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PICKERING NGS B 1988
LARVAL FISH ENTRAINMENT STUDY

Report No 89-295-K

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Chemical Research Department

ABSTRACT

Results of a larval fish entrainment study conducted in 1988 as part of the 1986-1988 Pickering NGS B postoperational aquatic program are presented. The objective of the study was to determine the species and abundance of entrained larval fish at Pickering NGS A and B. Alewife, rainbow smelt, round whitefish, carp, sucker (white or longnose), white bass or gizzard shad, walleye, white perch and unidentified cyprinid and salmonid eggs were entrained. Fish larvae entrained included alewife, rainbow smelt, round whitefish, carp and sucker (white or longnose). Entrainment of round whitefish larvae in 1988 represented the reproductive output of 96 spawning females at last spawn. Annual entrainment of rainbow smelt eggs and larvae were equivalent to the reproductive output of 111,000 spawning females at last spawn and that of alewife was equivalent to the reproductive output of 173,000 females. The early seasonal presence of walleye eggs in the entrainment samples suggest that they may spawn in the thermal plume.

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EXECUTIVE SUMMARY

PICKERING NGS B 1988 LARVAL FISH ENTRAINMENT STUDY

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Chemical Research Department

A larval fish entrainment study was conducted at Pickering NGS in 1988 as part of the 1986-1988 Pickering NGS B postoperational aquatic program. The study was requested by the Environmental Studies and Assessments Department of the Design and Development - Generation Division, on behalf of Pickering Engineering. The objective of the study was to determine the species and abundance of entrained larval fish at Pickering NGS A and B. Entrainment studies have been conducted at Pickering NGS in past years when only Pickering NGS A was operational. The significance of the numbers of larval fish entrained was determined in terms of the reproductive output of spawning females.

The target species were round whitefish, alewife and rainbow smelt and the sampling procedures were designed to detect these species. An attempt was also made to estimate the proportion of live alewife larvae collected in the Pickering NGS intake. Historically, the larvae reported to be entrained at Pickering have consisted almost entirely of alewife and rainbow smelt larvae. Although round whitefish larvae had not been collected in entrainment samples, they were caught in lake larval tows taken near the station. In previous studies sampling was generally initiated after the expected hatching period for round whitefish. All three species are known to spawn in the vicinity of Pickering NGS.

The larval fish entrainment study addressed hypotheses of effect that formed the basis for the Pickering NGS postoperational aquatic study program. The hypothesis concerning round whitefish was that the Pickering NGS thermal plume and cooling water intake would decrease round whitefish populations through hatch advancement and entrainment of larvae. The hypothesis concerning alewife and rainbow smelt was that entrainment mortality of larval fish and impingement of adults would result in the gradual decline of these

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populations. Other hypotheses concerned the entrainment of walleye and smallmouth bass larvae resulting from spawning of these species in the discharge.

Round whitefish larvae were entrained from March 15 to April 27 at Pickering NGS, with the majority of larvae (82%) taken at Pickering NGS A. Annual entrainment of round whitefish larvae was the equivalent of the reproductive output of 96 spawning females at last spawn. The early seasonal occurrence and early post-hatch size of round whitefish larvae in the entrainment samples, suggest that they spawn in the thermal plume.

Rainbow smelt eggs were entrained between March 18 and July 7. Larvae were entrained between April 29 and July 20. The densities of the eggs were substantially higher than those of the larvae. Annual entrainment of eggs and larvae was equivalent to the reproductive output of 111,000 spawning females at last spawn, with 41% of this loss attributed to Pickering NGS A.

Alewife eggs were entrained between June 20 and August 25, and larvae were entrained from July 25 to August 2. The annual entrainment of alewife eggs and larvae were equivalent to the reproductive output of 173,000 spawning females at last spawn, with 25% of this loss attributed to Pickering NGS A.

The hypothesis that cropping by Pickering NGS may result in declines in the round whitefish, rainbow smelt and alewife populations is a possibility. However, the proportions of the populations affected by Pickering NGS and the nature of compensatory mechanisms that exist within the populations are unknown.

The seasonal occurrence of walleye eggs in the entrainment samples suggests that they spawn in the thermal plume. Therefore, the hypothesis that the Pickering NGS thermal discharge may decrease walleye stock through entrainment and hatch advancement cannot be disregarded.

Mortality of alewife larvae in the intake, which represented both natural and handling mortality, ranged from 89 to 100% at Pickering NGS A and 87 to 100% at Pickering NGS B.

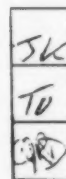


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To Dr. W.R. Effer
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PICKERING NGS B 1988 LARVAL FISH ENTRAINMENT STUDY

1.0 INTRODUCTION

A larval fish entrainment study was conducted at Pickering NGS in 1988 as part of the 1986-1988 Pickering NGS B postoperational aquatic program. The study was requested by the Environmental Studies and Assessments Department of the Design and Development - Generation Division, on behalf of Pickering Engineering. The objective of the study was to determine the species and abundance of entrained larval fish at Pickering NGS A and B. Although entrainment studies have been carried out at Pickering NGS in previous years, they were conducted when only Pickering NGS A was operational (Ontario Hydro Research Division Report Nos 81-211-K, 82-460-K, 82-85-K, 83-193-K and 85-59-K).

The significance of the numbers of larval fish entrained was determined in terms of the reproductive output of spawning females at last spawn. Because the current study was to be only one year in duration, and considering the large annual variation in larval fish densities, no attempt was made to establish a relation between total entrainment and number of operating units.

Pickering NGS A and B are adjacent nuclear stations located on the north shore of Lake Ontario at Pickering, Ontario. Each station consists of four 540 MW CANDU reactors. The two stations have a common surface condenser cooling water intake. Pickering NGS A uses 30.8 m^3 of cooling water per unit per second and discharges its cooling water to the west of the site. Pickering NGS B uses 33.4 m^3 of cooling water per unit per second and discharges to the east. The temperature rise across the condenser, with two pumps per unit and four units operating, is estimated at 9.7°C for Pickering NGS A and 9.2°C for Pickering NGS B (RMEP-IR-07211-1). The condenser cooling water passes through condenser tubes 15 m long with an outer diameter of 2.5 cm at a rate of 2.1 m/s.

Combined operational capacity in 1988 was either six or seven units for most of the year. Units 1, 5, 6 and 7 had occasional short outages over the year. Unit 2 had been down since August, 1983, for pressure tube replacement and came back on line in October, 1988, after the completion of the entrainment study. Planned and maintenance outages during the study period took place from late-March to late-April for Unit 3, and from mid-May to early-July for Unit 8.

The hypotheses of effect that formed the basis for studies included in the Pickering NGS B postoperational aquatic program were derived at an earlier workshop (Greig et al. 1986). The 1988 entrainment study is concerned with several of these hypotheses.

The target species for the present study were round whitefish (*Prosopium cylindraceum*), alewife (*Alosa pseudoharengus*), and rainbow smelt (*Osmerus mordax*) and the sampling procedures were designed to detect these species. Alewife and rainbow smelt larvae were predominant in entrainment catches at Pickering NGS in past studies (Ontario Hydro Research Division Report Nos 81-211-K, 82-460-K and 83-193-K). Although round whitefish larvae have not been collected in entrainment samples, they have been caught in lake larval tows around the station (Ontario Hydro Research Division Report No 84-135-K). Previous entrainment studies, however, were not conducted early in the year, the time when round whitefish larvae would be susceptible to entrainment. All three species are known to spawn in the vicinity of Pickering NGS.

The hypothesis concerning round whitefish was that the Pickering NGS thermal plume and water intake would decrease round whitefish populations through hatch advancement and entrainment of larvae (Greig et al. 1986). The hypothesis derived for alewife and rainbow smelt was that entrainment mortality of larval fish and impingement of adults would result in the gradual decline of these populations.

It was also suggested at the workshop that walleye (*Stizostedion vitreum*) and smallmouth bass (*Micropterus dolomieu*) larvae may be entrained if they spawn in the discharges. Both species were present in the discharge areas during their expected spawning periods in 1987 and 1988 (Ontario Hydro Research Division Report Nos 88-267-K and 89-253-K). Walleye spawning was not observed in the discharges during these studies and therefore entrainment of this species was not expected. Smallmouth bass spawned in the Pickering NGS B discharge in both years. However, centrarchid entrainment was expected to be minimal since they spend their early development in nests, thereby avoiding offshore displacement. Therefore, sampling effort was not designed to collect smallmouth bass larvae.

In addition to determining the species composition and abundance of entrained larvae, an attempt was made to estimate the proportion of live alewife larvae in the Pickering NGS intake.

2.0 METHODS

Sampling Locations

Larval net and pump samples were collected from the condenser cooling water (CCW) currents in the Pickering NGS intake channel, south of the skimmer wall on the Pickering NGS A side, and between the resistance temperature device (RTD) support structures 1 and 2 on the Pickering NGS B side (Figure 1). Sampling was conducted from rafts installed at these two locations (Figure 2).

In addition, four passive samplers were placed at the bottom, across the common intake channel, about 20 m south of the intake branch leading to Pickering NGS B (Figure 1).

Sample Volume

The volume of water sampled over the study period depended on the expected densities of the target species. The minimum volume sampled in a day was determined by the lowest larval densities which would give a value considered to be of potential significance when extrapolated to total numbers entrained. For round whitefish a minimum volume of 1,000 m³ of water was filtered per sampling day, 150 m³ for rainbow smelt, and 100 m³ for alewife. The detection of a single larvae within each of these volumes could be equated to the reproductive output of 37, 2,000 and 1,400 spawning females, respectively.

Sampling Schedule

Sampling was scheduled for two days a week. However, when eggs were present in the samples, the effort was increased to three times a week and when larvae were present, sampling was conducted daily. Samples were collected on a total of 73 days between March 15 and September 1, 1988.

Sampling Gear

Four types of samplers were used over the course of the study: 1.0 m conical nets, 0.5 m conical nets, passive samplers, and pump-and-net systems (Figures 2,3). The time periods sampled and volumes of water sampled using quantitative sampling gear (1.0 m conical nets and pump-and-net systems) are presented in Table 1. Sampling gear and installations used in the present study are described in detail in Appendix 1.

1.0 m Conical Net

Conical nets with a 1.0 m diameter, a length to width ratio of 3:1, and a mesh size of 565 µm were used to sample round whitefish larvae. This mesh size was selected because it ensured the capture of round whitefish larvae without excessive clogging of the nets and facilitated sampling large water volumes. At Pickering NGS B, the net was suspended between the most northerly RTD support structure, about 0.5 m below the surface, from March 15 through March 22. From March 22 to April 29, the net was placed in the preferred position, 0.5 m off the bottom. At Pickering NGS A the net was placed off the bottom from March 29 through April 29. The bottom waters were sampled because round whitefish larvae are benthic. The nets were equipped with General Oceanics flow meters, located centrally within the opening of the nets. The nets filter at a rate of about 14 m³ per minute at a current speed of 30 cm/sec. The average current at Pickering NGS A was 15 cm/sec and at Pickering NGS B it was 70 cm/sec. The nets were left in the CCW current for at least 2 hours when day samples were collected. In addition to the day tows, nets were left in overnight on sampling days between March 15 and March 29. Data collected with the 1.0 m conical net are presented in Appendix 2.

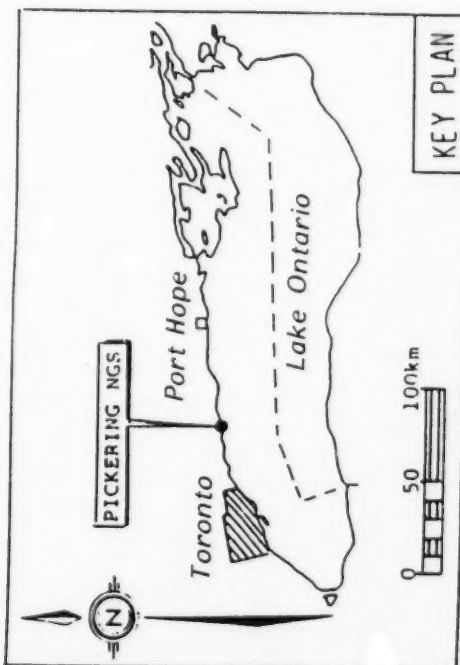
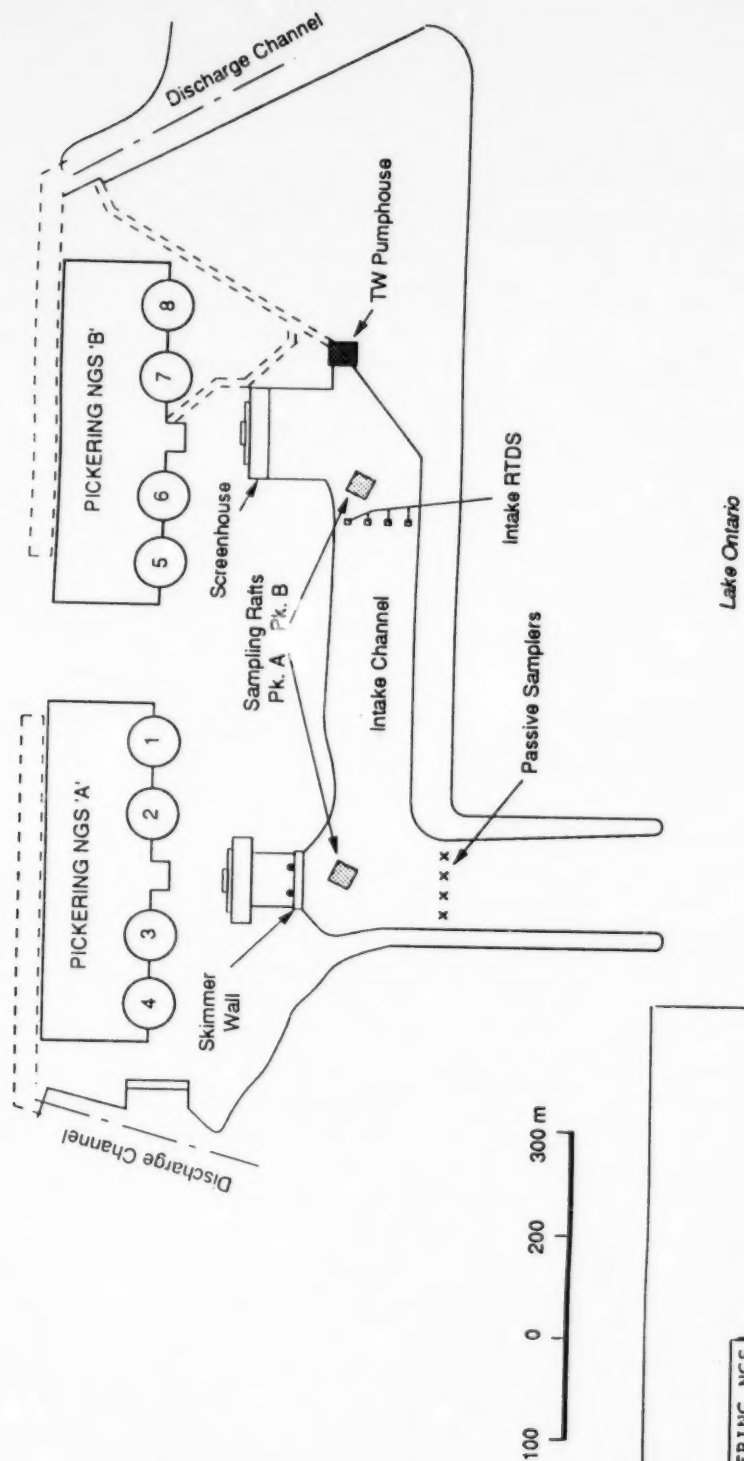


FIGURE 1
PICKERING NGS 'A' AND 'B'
ENTRAINMENT SAMPLING LOCATIONS

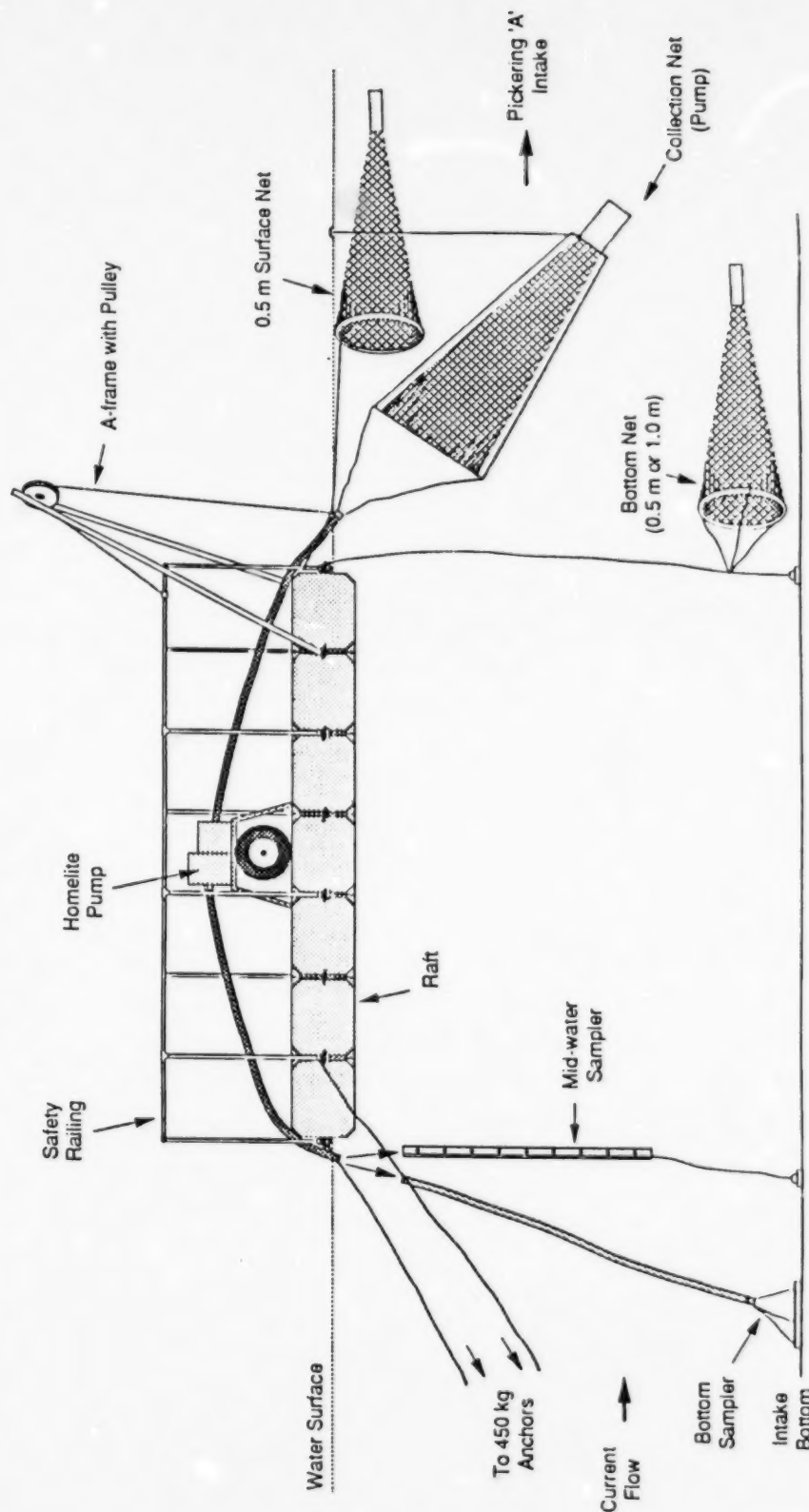


FIGURE 2
 DIAGRAMMATIC REPRESENTATION OF ENTRAINMENT SAMPLING
 SET-UP AT PICKERING NGS 'A'

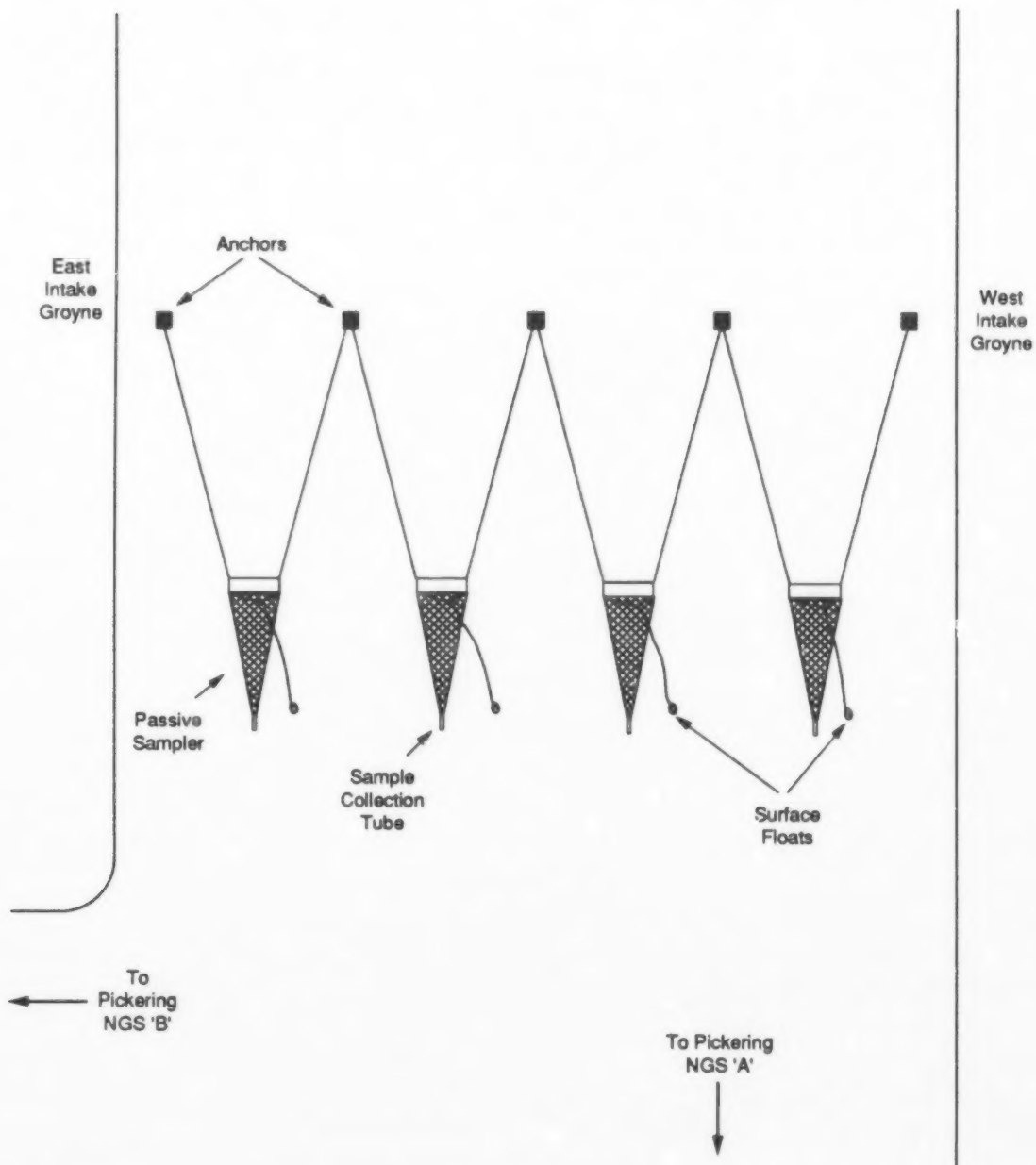


FIGURE 3
DEPLOYMENT OF PASSIVE SAMPLERS
DURING ENTRAINMENT SAMPLING
PICKERING INTAKE, 1988

TABLE 1

SAMPLING SCHEDULE

LOCATION	SAMPLING GEAR	SAMPLING PERIOD	VOLUME FILTERED (M3)
PICKERING NGS A	1.0 M CONICAL NET	MARCH 29 - APRIL 29	64668
	0.5 M CONICAL NET	APRIL 20 - JULY 27	NA
	PUMP-AND-NET SYSTEM		
	- BOTTOM	MARCH 29 - APRIL 29	11003
	- MID-DEPTH	MAY 2 - SEPT 1	7409
PICKERING NGS B	1.0 M CONICAL NET	MARCH 15 - APRIL 29	219660
	0.5 M LARVAL TOW NET	APRIL 20 - 29	NA
	PUMP-AND-NET SYSTEM		
	- BOTTOM	MARCH 29 - APRIL 29	9942
	- MID-DEPTH	MAY 2 - AUGUST 25	6234
COMMON INTAKE CHANNEL	PASSIVE SAMPLERS	APRIL 13 - 29	NA

TOTAL VOLUME OF WATER FILTERED 318916

NA - NOT APPLICABLE

0.5 m Conical Nets

Conical nets with 0.5 m diameter, length to diameter ratio of 3:1, and a mesh size of 363 μm were used as qualitative samplers. They were used to sample surface waters for rainbow smelt eggs and larvae when quantitative samples (1.0 m conical net and pump samples) were being collected at the bottom and vice versa. At Pickering NGS A a 0.5 m net was suspended off the raft, near the surface from April 20 - 29 and 0.5 m off the bottom from May 3 to July 27. At Pickering NGS B the surface waters were sampled with this net from April 20 - 29.

Discussion on these data are limited to the cases where fish eggs or larvae were present in the qualitative samples and not in the quantitative samples (Appendix 3).

Passive Samplers

The passive samplers were also used as qualitative samplers and consisted of stationary nets (363 μm mesh) with collection tubes attached to the ends. A metal frame at the opening of the nets ensured that the nets stayed open. The sampler was designed to collect round whitefish larvae under conditions of low current flow (Griffiths, unpublished data). Four samplers were placed about 15 m apart across the bottom of the common intake channel such that the bottom stratum could be sampled continuously (Figure 3). Samplers were checked daily, Monday through Friday, from April 13 - 29 (Appendix 4).

Pump-and-Net System

The pump-and-net system is an effective way of obtaining an integrated sample over time (Ontario Hydro Research Division Report Nos 80-186-K, 85-59-K and 86-190-K). It has been found to collect viable larvae and is therefore better suited than nets for assessing the proportion of larvae that are alive. The average pumping rate was 2.1 m^3 per minute. Homelite trash pumps with nets attached to the outlet hoses (10 cm dia) were used to collect quantitative samples from March 29 through September 1 at Pickering NGS A, and from March 29 through August 25 at Pickering NGS B. Failure of the pump at Pickering NGS B accounted for the shorter sampling period at that location.

The pump-and-net system was used to collect samples near the bottom from March 29 through April 29, and at mid-depth for the duration of the sampling program. When sampling for round whitefish larvae, samples were collected between 9 am and 2 pm. For rainbow smelt larvae, sampling was conducted between 9 and 11 am, and for alewife, samples were collected between 9 and 10 am.

Comparison of daytime and nighttime entrainment of larvae was conducted at Pickering NGS A in 1976 and 1977 (Ontario Hydro Research Division Report Nos 77-152-K and 78-322-K). Larger numbers of rainbow smelt larvae were collected in day samples in both years. In the case of alewife larger numbers were collected in day samples in 1976. In 1977, with the exception of one

sampling day when higher numbers were taken in the night sample, the number of alewife larvae collected in day and night samples were comparable. On the basis of these results, daytime sampling for rainbow smelt and alewife larvae was considered sufficient for estimating entrainment. In the case of round whitefish larvae, 1.0 m conical nets were left in for 24-hr periods on sampling occasions between March 15 and 28 for quantitative checks of species composition. The passive samplers provided qualitative checks which included nights.

Bottom sampling was carried out using the support bracket shown in Figure 4. It consisted of a 61 cm square steel plate attached to a sleeve of 12.7 cm diameter steel pipe. A 10 cm steel tube, which could be adjusted to sample 10 to 30 cm above the steel plate, passed through the sleeve. The tube was inclined at a 15° angle and had coarse screening (2.5 X 5.0 cm steel mesh) over the lower end to exclude large fish. Flexible tubing (10 cm dia.) connected the steel tube within the support bracket to the pump.

To sample mid-water, a 10 cm diameter polyvinyl chloride sampling tube, with two rows of holes (2.5 cm openings) spaced 7.6 cm apart, was attached to the pump intake hose (Figure 4). The length of the sampling tube used at the Pickering NGS A location was 2.4 m with 16 holes spaced 33 cm apart. At the Pickering NGS B location, a tube 1.2 m long with 16 holes spaced 15 cm apart was used. The lengths of the tubes differed at the two locations because depth at the two sites differed. The depth at the Pickering NGS A location was 3.9 m and at the Pickering NGS B location it was 2.4 m. However, the sampling area along the two tubes were similar and added up to 81 cm² in each case. The tubes were placed vertically in the water column with the holes facing the current.

Between March 29 and May 5 a 0.5 m conical net was used to strain pump samples. A 0.5 m (diameter) Hensen egg net with 363 µm mesh was attached to the discharge hose of the pump from May 5 to the end of the study period. The nets were suspended within a steel frame to ensure that it remained open during pumping.

From March 29 through April 29, three consecutive samples were collected daily from each location (A and B). The fuel capacity of the pumps allowed them to run for about one and a half hours. With the large volumes of water pumped during the period when round whitefish was the target species, refueling was required twice on each sampling date. One sample per day per location was collected for the remainder of the study period. Data collected with the pump-and-net systems are presented in Appendix 5 for Pickering NGS A and in Appendix 6 for Pickering NGS B.

Sample Analyses

Samples for species composition and abundance estimates were preserved in 5% formalin following collection and cursory examination. The samples were then sorted for fish eggs and larvae which were identified and counted (Auer 1982). Of the three daily pump samples collected between April 7 and April 29, only

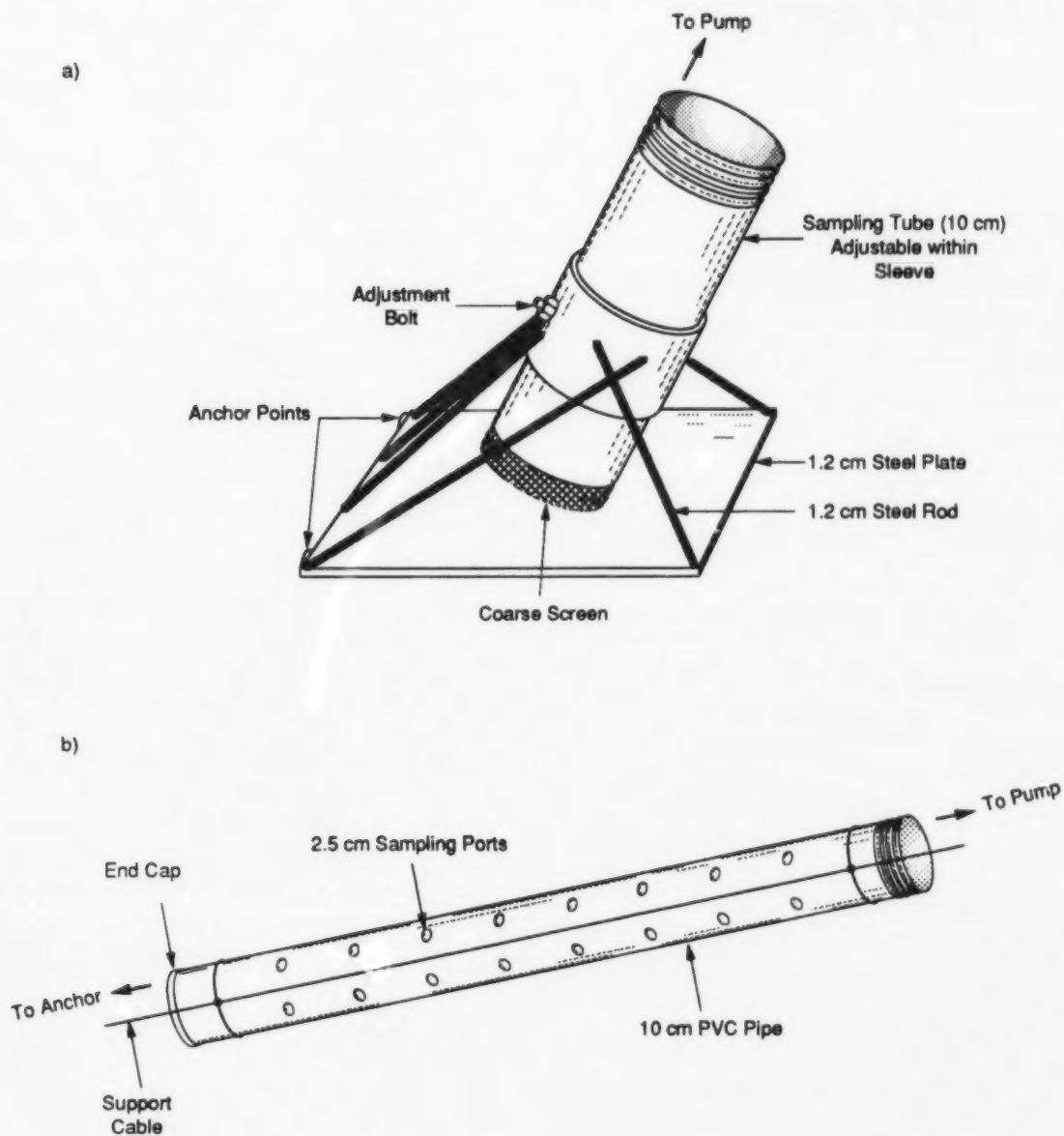


FIGURE 4

ENTRAINMENT SAMPLING GEAR

a) BOTTOM SAMPLER FOR HOMELITE PUMP

b) MIDWATER SAMPLER FOR HOMELITE PUMP

one sample was sorted for smelt eggs. Complete sorting was conducted on all other samples. In addition, lengths of a portion of the larvae caught were measured (a maximum of 41 per species per sample day).

Densities were calculated for eggs and larvae caught with the 1.0 m conical nets and pump-and-net systems. In the case of the 1.0 m conical nets, the flow meter readings were used to obtain volume of water filtered, and in the case of the pump, average pumping rate and pumping time were used.

Data Analyses

To estimate the total numbers of eggs and larvae entrained at Pickering NGS A and B, a linear interpolation on density was done between sampling dates to estimate missing values. The number of fish eggs and larvae entrained in a day for a particular species was then calculated as follows:

$$\begin{array}{lcl} \text{Number} & & \\ \text{of Fish} & - \text{Density} \times \text{CCW Flow Rate} \times \text{Seconds in a Day} & \\ \text{Entrained} & (\text{m}^3/\text{sec}) & (86400 \text{ seconds}) \end{array}$$

Daily mean CCW flow values, reported by Pickering NGS, were used in the calculations. Summing the daily entrainment estimates provided the total annual entrainment estimates.

Total annual entrainment of larvae were then related to numbers of spawning females by applying egg survival rates and fecundity estimates for each species (Ontario Hydro Research Division Report No 80-382-K) as follows:

$$\text{No of Spawning Females} = \frac{\text{No of Larvae} \times \text{Egg Survival}}{\text{Fecundity}}$$

Live-Dead Determinations

Alewife mortality estimates were made from July 28 through August 4 to assess the proportion of dead larvae in the intake. Since handling mortality was not assessed, the mortality measured included both natural and handling mortality. Live-dead sorting was only conducted on days when the densities of the larvae were >30 animals per 100 m^3 . To do live-dead determinations, the sampling interval must be short to minimize handling mortality. Therefore, the densities of the larvae must be high enough that reasonable numbers can be collected within a short sampling period.

Three consecutive samples, of 15 to 20 minute duration, were taken per day, at each of the two locations, with the pump-and-net system. These samples were immediately sorted for dead animals. The remainder of the samples were preserved and sorted on a later date for larvae that were collected alive. Immediate sorting was for dead larvae because they were more visible than live larvae.

3.0 RESULTS AND DISCUSSION

Water Temperature

Inlet cooling water indicated a gradual rise in temperature from March through May after which temperatures dropped 2-3°C (Figure 5). This was followed by the rapid warming of the water through July. Sharp drops in temperature, typical of upwellings, occurred several times during the summer and early fall. The temperature dropped in mid-October and remained low for the rest of the year.

Entrainment

Species Composition

The species composition of fish eggs and larvae collected with the 1.0 m larval tow nets and the pump-and-net system are presented in Table 2. Eggs of at least nine fish species and larvae of five species were collected in the Pickering NGS (A and B) entrainment samples.

Eggs belonging to alewife, rainbow smelt, and carp, white bass or gizzard shad, walleye and white perch were taken at both sites. Sucker (white sucker or longnose sucker) eggs and an unidentified cyprinid egg were only taken at Pickering NGS A, and whitefish (probably round whitefish) eggs were only taken at Pickering NGS B.

Alewife, rainbow smelt, round whitefish and carp larvae were collected at both sites and a sucker (white or longnose) larvae was collected at Pickering NGS A.

Larvae caught in previous years that were not taken during this study were gizzard shad, sculpin (Ontario Hydro Research Division Report No 81-211-K) and yellow perch (Ontario Hydro Research Division Report 82-460-K). Larvae caught during the present study that had not been taken in previous studies were round whitefish and sucker. The absence of round whitefish in previous years was probably related to the late date at which sampling was started (mid-April or May), as well as the limited volumes of water sampled. In addition nets were placed higher up in the water column in past years.

Round whitefish eggs and larvae, and walleye eggs were caught in the 1.0 m conical nets and the pump-and-net bottom samples. Smelt eggs and larvae were taken in the pump-and-net bottom and mid-depth samples. Alewife and carp eggs and larvae were taken in the mid-depth pump-and-net samples.

Round Whitefish

Mean weekly densities of round whitefish entrained at Pickering NGS A and B are presented in Figure 6.

FIGURE 5: PICKERING NGS B

MEAN DAILY TEMPERATURES

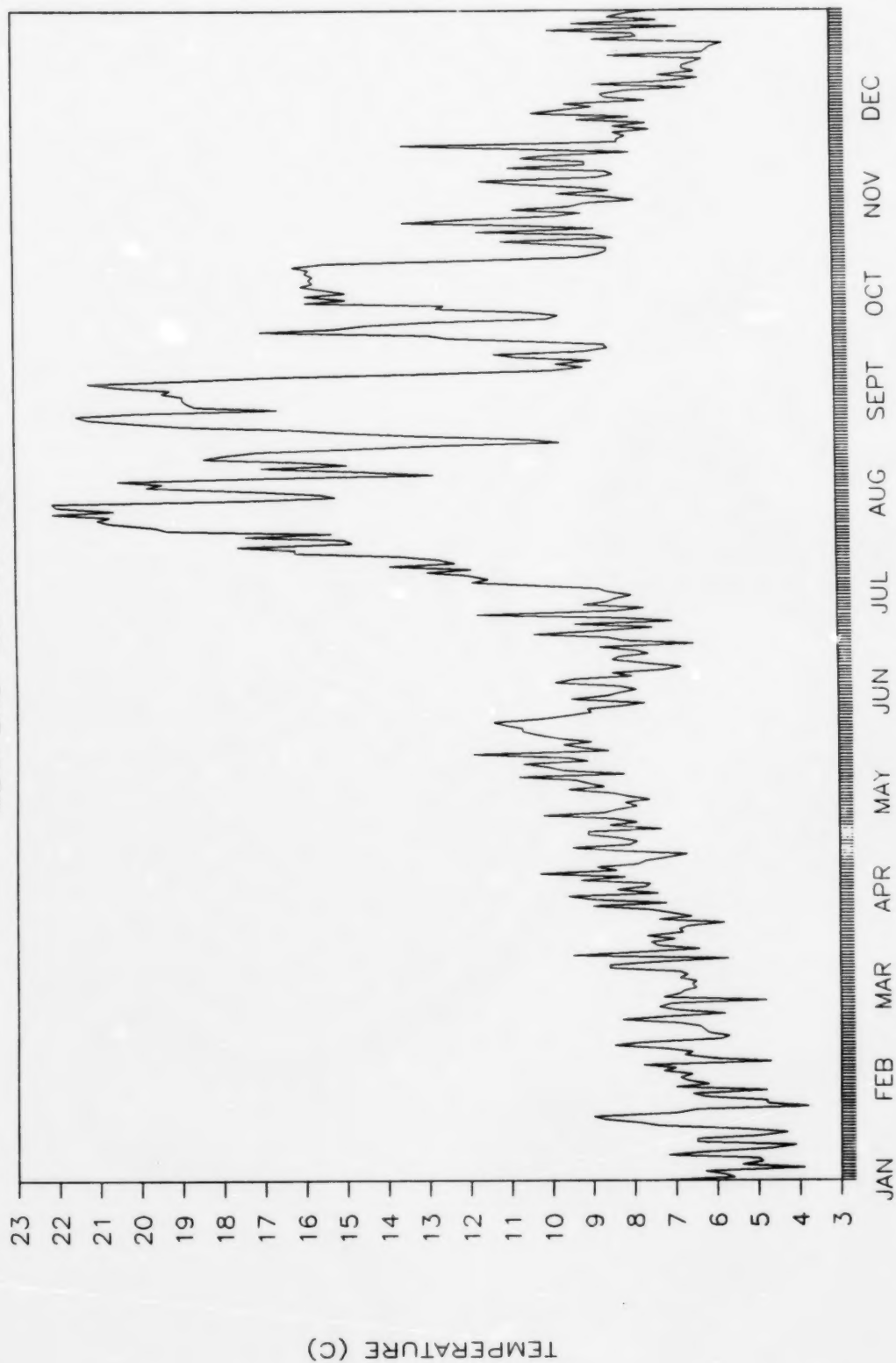
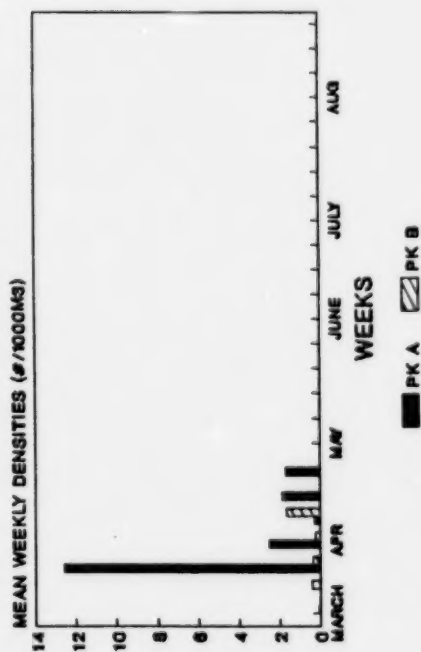


TABLE 2

SPECIES COMPOSITION OF FISH EGGS AND LARVAE COLLECTED IN
1988 PICKERING NGS A AND B ENTRAINMENT SAMPLES

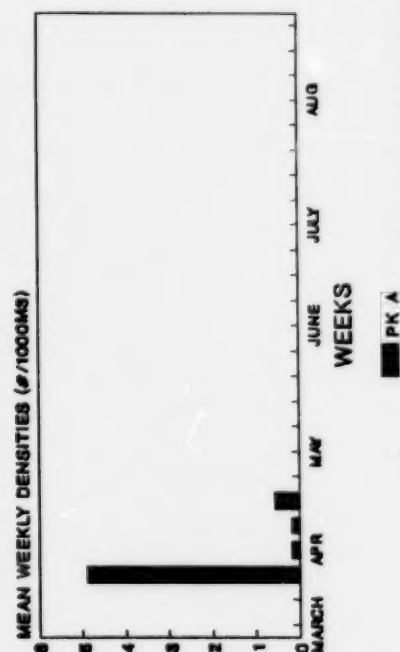
SPECIES	PICKERING NGS A		PICKERING NGS B	
	EGGS	LARVAE	EGGS	LARVAE
ALEWIFE	X	X	X	X
RAINBOW SMELT	X	X	X	X
ROUND WHITEFISH	-	X	X	X
CARP	X	X	X	X
SUCKER (WHITE OR LONGNOSE)	X	X	-	-
WHITE BASS OR GIZZARD SHAD	X	-	X	-
WALLEYE	X	-	X	-
WHITE PERCH	X	-	X	-
CYPRINID	X	-	-	-
X PRESENT				
- ABSENT				

ROUND WHITEFISH LARVAL FISH DENSITIES
PICKERING NGS A AND B, 1988

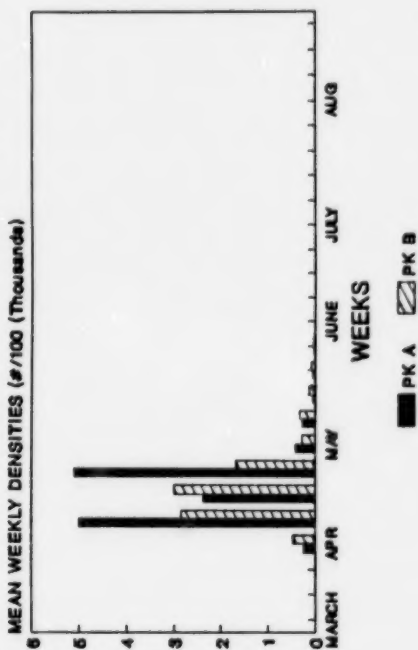


WALLEYE EGG DENSITIES

PICKERING NGS A



RAINBOW SMELT EGG DENSITIES PICKERING NGS A AND B, 1988



RAINBOW SMELT LARVAL FISH DENSITIES PICKERING NGS A AND B

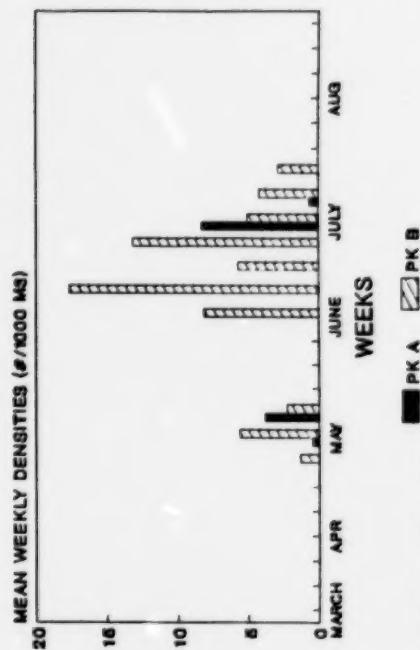


**FIGURE 6: ENTRAINMENT OF FISH EGGS AND LARVAE
AT PICKERING NG3, 1988.**

At Pickering NGS A, round whitefish larvae were caught on the very first sampling day, March 29, and occasional specimens were taken up to April 27. The highest density, estimated for March 30, was 7 larvae/1,000 m³. A total of 11 round whitefish were collected at this location.

At Pickering NGS B, round whitefish larvae were also caught on the first sampling date, March 15, and were taken off and on, up to April 11. Two round whitefish eggs were, however, caught at this site on April 15. The highest density of round whitefish larvae at this location was 0.5 larvae/1,000 m³, obtained on April 11.

Griffiths (Ontario Hydro Research Division Report No 87-181-K) carried out an in-situ egg incubation study between the Rouge River, to the west of Pickering NGS, and Thickson Point in the east. He found that with an average temperature rise of 3.0°C, eggs incubated at the Pickering NGS B discharge hatched 4-5 weeks before those at Thickson Point. The eggs at ambient lake temperature off Thickson Point hatched out in mid-April.

The predicted hatch dates for round whitefish larvae in 1988 were calculated using the egg development model developed by Griffiths (Ontario Hydro Research Division Report No 89-253-K). Mean daily temperatures for Ontario Hydro Geotechnical and Hydraulic Engineering locations TH06 and THB01 were used to calculate hatch dates for ambient temperature and plume conditions, respectively. Location TH06 is a 12 m spar, 1.3 km offshore from Pickering NGS, and THB01 is a 3.0 m spar, 0.3 km offshore. Temperatures at a 5.0 m depth spar in the plume were used to fill in missing data for THB01. The spawn dates and corresponding 50% and complete hatch dates are presented in Table 3.

At ambient temperatures, with an early spawn date of December 1, 50% hatch is predicted for March 30, and complete hatch on April 22. However, round whitefish gill net catches during the 1986-1988 Pickering NGS B spawning surveys (Ontario Hydro Research Division Report No 89-149-K) suggest that the peak spawning migration typically occurs in mid-December. With a spawning date of December 14, 50% hatch at ambient temperatures is predicted for April 15 - 16, and complete hatch on April 30. The early occurrence of round whitefish larvae in our entrainment samples suggests that at least a portion of the larvae hatched out in the thermal plume.

Round whitefish larvae collected during this study varied between 9.7 and 15 mm in length (Table 4). Newly hatched larvae are approximately 12 to 14 mm long (Ontario Hydro Research Division Report No 83-57-K). This suggests that the larvae hatched out over a period of about one month from eggs that had been deposited at different locations within and outside of the thermal plume at variable incubation temperatures. Rapid offshore displacement may account for the lack of larger larvae in the samples.

Annual entrainment of round whitefish larvae was estimated at 110,000: 90,000 for Pickering NGS A and 20,000 for Pickering NGS B (Table 5).

TABLE 3

PREDICTED HATCH DATES FOR ROUND WHITEFISH EGGS
UNDER PLUME AND AMBIENT TEMPERATURES

PLUME TEMPERATURES

3 M SPAR, 0.4 KM OFFSHORE (5 M SPAR FOR APRIL AND MAY)¹

SPAWN DATE	50% HATCH	COMPLETE HATCH
DEC 1, 1987	JAN 21-22, 1988	JAN 31, 1988
DEC 7, 1987	JAN 27-28, 1988	FEB 5, 1988
DEC 14, 1987	FEB 1, 1988	FEB 10, 1988
DEC 21, 1987	FEB 10-11, 1988	FEB 16, 1988

AMBIENT TEMPERATURES

12 M SPAR, 1.3 KM OFFSHORE²

SPAWN DATE	50% HATCH	COMPLETE HATCH
DEC 1, 1987	MARCH 30, 1988	APRIL 22, 1988
DEC 7, 1987	APR 7, 1988	APR 29, 1988
DEC 14, 1987	APR 15-16, 1988	APR 30, 1988
DEC 21, 1987	APR 22, 1988	APR 30, 1988

- 1 - ONT. HYDRO GEOTECHNICAL AND HYDRAULIC ENGINEERING SPAR TH06
2 - ONT. HYDRO GEOTECHNICAL AND HYDRAULIC ENGINEERING SPAR THB0

TABLE 4

MEAN LENGTHS OF LARVAE (mm)
COLLECTED IN 1988 AT PICKERING NGS A AND B

DATE	MEAN LENGTH	SD	MEASURED
ROUND WHITEFISH			
MARCH 15	13.5		1
MARCH 23	9.7		1
MARCH 24	14.3	0.2	3
MARCH 29	13.8	0.7	3
MARCH 30	12.5	0.2	3
APRIL 7	12.3	1.8	2
APRIL 11	13.5	0.0	2
APRIL 15	15.0		1
APRIL 18	14.0	1.5	2
APRIL 27	14.5	0.0	2
RAINBOW SMELT			
APRIL 29	5.7		1
MAY 5	5.0	0.5	2
MAY 9~	5.0	0.6	3
MAY 16	5.5		1
MAY 20	6.4	0.4	2
JUNE 10	6.0	0.0	4
JUNE 17	6.6	1.7	8
JUNE 23	9.5		1
JUNE 30	8.8	1.0	4
JULY 4	7.5		1
JULY 7	7.2	0.8	3
JULY 11	8.3	0.3	2
JULY 20	9.5		1
ALEWIFE			
JULY 25	2.9	0.8	11
JULY 26	2.9	0.3	4
JULY 27	3.8	0.5	30
JULY 28	3.6	0.4	41
JULY 29	4.1	0.7	36
JULY 30	4.9	1.5	5
AUG 2	3.7	3.7	3

TABLE 5

ANNUAL ENTRAINMENT AND EQUIVALENCE IN SPAWNING FEMALES OF FISH EGGS AND LARVAE
ENTRAINED AT PICKERING NGS A AND B IN 1988

	TOTAL ANNUAL ENTRAINMENT		EQUIVALENT NUMBER OF SPAWNING FEMALES ¹		
	PICKERING NGS A MILLIONS	PICKERING NGS B	PICKERING NGS A	PICKERING NGS B	TOTAL
ROUND WHITEFISH LARVAE	0.09	0.02	79	17	96
RAINBOW SMELT EGGS	670	660	46000	65000	111000
RAINBOW SMELT LARVAE	0.6	4.0			
ALEWIFE EGGS	75	300	43000	130000	173000
ALEWIFE LARVAE	5.7	17			
WALLEYE EGGS	0.25	ID			
CARP EGGS	39	38			
CARP LARVAE	0.6	1.5			

ID - INSUFFICIENT DATA

1 - # OF SPAWNING FEMALES = # OF LARVAE X EGG SURVIVAL

FECUNDITY

In deriving the equivalent number of spawning females required to produce the total number of larvae entrained, a hatching success of 20% was used. This was close to the 22% hatching rate observed for eggs incubated at the 5 m depth in the Pickering NGS B discharge (Ontario Hydro Research Division Report No 87-181-K). The average fecundities for 4+, 5+ and 6+ fish (Ontario Hydro Research Division Report No 87-82-K) were applied in proportion to the age structure of round whitefish at Pickering (Ontario Hydro Research Division Report No 87-181-K) to obtain an average fecundity of 5,900. Under these assumptions, the larvae entrained at Pickering NGS A were equal to the combined reproductive output of 79 spawning females at last spawn (Table 5) and those entrained at Pickering NGS B were equivalent to the reproductive output of 17 females. Total annual entrainment at Pickering NGS was equivalent to the reproductive output of 96 spawning females at last spawn.

The protracted occurrence of round whitefish in the entrainment samples and the fact that the larvae were early post-hatch based on size, suggest that round whitefish spawn in areas affected by the thermal plume. Therefore, the hypothesis that the thermal plume and water intake would decrease round whitefish populations through egg hatch advancement and entrainment of larvae (Grieg et al. 1986) is a possibility. However, the proportion of the population affected, and the compensatory mechanisms that this population is capable of are not known.

Rainbow Smelt

Mean densities of rainbow smelt eggs and larvae entrained at Pickering NGS A and B are presented in Figure 6.

Rainbow smelt eggs were first collected on March 18, but were not counted until April 7. They were present in the samples until July 7. Maximum density was estimated for Pickering NGS A on April 13 (9100 eggs/1,000 m³).

Rainbow smelt larvae were caught from April 29 to July 20. They were only collected on two occasions at Pickering NGS A. Maximum density of 53 larvae/1,000 m³ occurred at Pickering NGS B on June 15. The peak densities of smelt larvae at Pickering NGS A and B were much lower in 1988 than they had been in previous studies (Table 6). A slight drop in temperature occurred in late-May (Figure 5) and somewhat lower temperatures, comparable to April and early-May temperatures, persisted through June. This drop in temperature may have prolonged hatching, but probably does not account for the low densities of rainbow smelt larvae.

In past studies rainbow smelt larvae were present at the start of the sampling period in April or May with peak entrainment found in late-May or early-June (Ontario Hydro Research Division Report Nos 81-211-K, 82-460-K, 83-193-K and 82-85-K). The occurrences of rainbow smelt eggs and larvae in the entrainment samples coincide with their expected spawning runs in March-May (Scott and Crossman 1973).

TABLE 6
MAXIMUM DENSITIES OF ENTRAINED
RAINBOW SMELT AND ALEWIFE LARVAE AT PICKERING NGS
1975 - 1988

LOCATION		RAINBOW SMELT	ALEWIFE
		NO/1,000 M3	
PICKERING NGS A	1975	90	1000
	1		
PICKERING NGS A	1976	900	500
	1		
PICKERING NGS A	1977	500	10000
	2		
PICKERING NGS A	1980	780	NA
	(MARCH-JUNE ONLY)		
	3		
PICKERING NGS A	1981	260	2423
	(SURVEY DATA)		
	4		
PICKERING NGS A	1981	920	1065
	(ENTRAINMENT DATA)		
	5		
PICKERING NGS A	1984	NA	2250
	(JULY-AUGUST ONLY)		
PICKERING NGS A	1988	18	298
PICKERING NGS B	1988	53	460

NA - NO DATA

1 Ontario Hydro Research Division Report No 81-211-K

2 Ontario Hydro Research Division Report No 82-460-K

3 Ontario Hydro Research Division Report No 83-193-K

4 Ontario Hydro Research Division Report No 82-85-K

5 Ontario Hydro Research Division Report No 85-59-K

The mean size of smelt larvae increased over the period April 29 to June 23 (Table 4). Early post-hatch larvae, ranging in mean size from 5.0 to 5.7 mm were taken prior to May 20, while between May 20 and June 17 the range in mean larval size was 6.0 to 6.6 mm. The presence of developing smelt larvae were also observed at Pickering NGS in 1975-1977 (Ontario Hydro Research Division Report No 81-211-K). The lack of increase in mean size between June 23 and July 20 (range in mean lengths = 7.2 to 9.5 mm) suggests constant new recruitment. A similar suggestion was made based on the 1975-1977 data (Ontario Hydro Research Division Report No 81-211-K).

Annual entrainment of smelt eggs were estimated at 670 million at Pickering NGS A and 660 million at Pickering NGS B for a total of 1330 million (Table 5). Annual entrainment of smelt larvae was 0.6 million for Pickering NGS A, and 4.0 million for Pickering NGS B, for a total of 4.6 million. The number of larvae entrained was only 0.3% of the number of eggs entrained. Compared to an estimated hatching success of 1% (Ontario Hydro Research Division Report No 81-211-K), this is a reasonable ratio since it is influenced by variables such as current and station operation which could account for the difference.

Annual entrainment of smelt eggs at Pickering NGS A was estimated at 21 million in 1977. The higher estimates for entrained eggs obtained in the present study was due to the earlier start as compared to previous studies (Ontario Hydro Research Division Report No 81-211-K). Also, the eggs were more abundant at the bottom than at the surface (data from 0.5 m nets), and our densities were based on bottom samples. In earlier studies sampling was conducted higher up in the water column. Rainbow smelt eggs become adhesive shortly after extrusion (Scott and Crossman 1973). Although it is not known whether non-adhesive eggs will hatch out successfully, viable eggs were present in the samples. Annual entrainment of smelt larvae was estimated at 3 million in 1975, 12 million in 1976, and 44 million in 1977 (Ontario Hydro Research Division Report No 81-211-K). Estimates of annual entrainment of smelt were not made for other study years.

A hatching success of 1% and a mean fecundity of 16,200 were used (Ontario Hydro Research Division Report No 81-211-K) to estimate the equivalent number of spawning females that the annual entrainment of smelt eggs and larvae represented. Smelt eggs and larvae entrained at Pickering NGS A were equivalent to the reproductive output of 46,000 spawning females at last spawn and those entrained at Pickering NGS B would be equivalent to the reproductive output of 65,000. Therefore, the combined reproductive output of 111,000 spawning females at last spawn were lost to the lake system through entrainment at Pickering NGS assuming all entrained eggs and larvae were dead.

Rainbow smelt gill net catches in the Pickering NGS study area dropped substantially between 1979-1981 and 1986-1988 (Ontario Hydro Research Division Report No 89-149-K). This drop in the rainbow smelt numbers in Lake Ontario was hypothesized to be due to Lake trout predation (Christie et al. 1987). Entrainment at generating stations may aggravate this decline.

As hypothesized, cropping by Pickering NGS may result in a reduction in a segment of the rainbow smelt population. However, the significance of this loss must be assessed in terms of recruitment to the adult population.

Alewife

Mean weekly densities of alewife eggs and larvae entrained at Pickering NGS A and B are presented in Figure 7.

Alewife eggs were taken on most sampling dates between June 20 and August 25. Maximum density of 4200 eggs/1,000 m³ occurred at Pickering NGS B on July 25.

Alewife larvae were entrained over a period of eight days from July 25 to August 2. Highest density occurred at Pickering NGS B on July 28 (460 larvae/1,000 m³). The occurrence of alewife larvae in the entrainment samples coincided with the main warming trend of the water (Figure 5).

Maximum densities of alewife larvae at Pickering NGS A and B in 1988 were lower than they had been in previous entrainment studies conducted at Pickering NGS (Table 6).

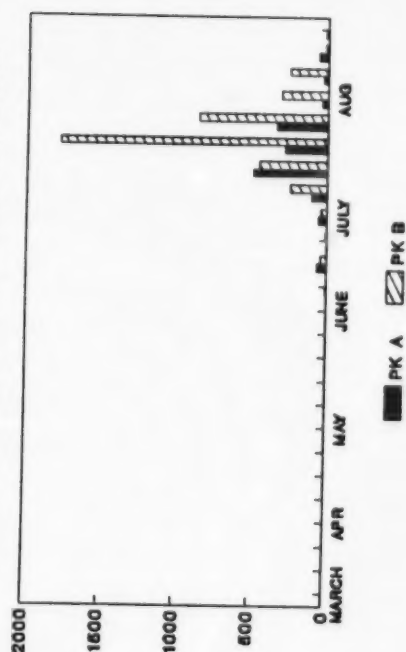
In past years, alewife larvae entrainment started in late-June or July with peak densities found in late July or early August (Ontario Hydro Research Division Report Nos 81-211-K, 82-85-K, and 83-193-K). The exception was 1982, when alewife larvae were only entrained in August (Ontario Hydro Research Division Report No 83-435-K). According to Graham (1957) the inshore movement of spawning alewife in Lake Ontario occurs from April to mid-July.

The mean size of alewife larvae ranged from 2.9 mm to 4.9 mm (Table 4). Larvae within this size range are in the early post-hatch stage of development (Ontario Hydro Research Division Report No 81-211-K). The slight increase in mean length of alewife larvae during the present study and the 1975 and 1977 studies were quite similar suggesting rapid dispersal of these larvae from the nearshore area (Ontario Hydro Research Division Report No 81-211-K).

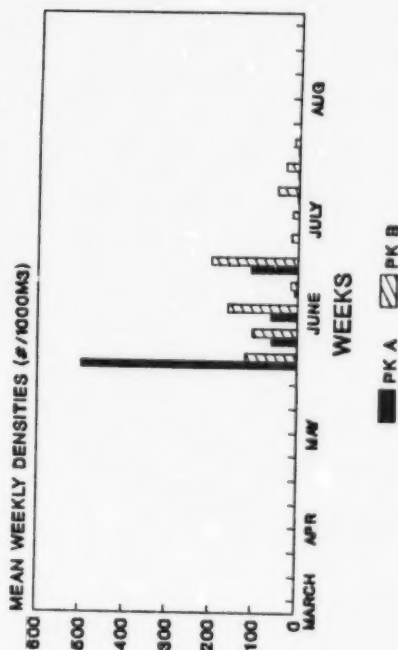
Annual entrainment of alewife eggs at Pickering NGS was 375 million: 75 million at Pickering NGS A and 300 million at Pickering NGS B (Table 5). Annual entrainment of alewife larvae was 23 million, with 78% entrained at Pickering NGS B. In 1975, 81 million alewife larvae were entrained at Pickering NGS A, in 1976, 19 million larvae were entrained, and in 1977, 320 million larvae and 5,300 million eggs were entrained (Ontario Hydro Research Division Report No 81-211-K). The number of larvae entrained during the present study at Pickering NGS A was close to that entrained in 1976.

A 1% hatching survival and a mean fecundity of 15,200 (Ontario Hydro Research Division Report No 81-211-K) was applied to the numbers of entrained alewife eggs and larvae to relate them to the reproductive output of spawning females. Annual entrainment of alewife eggs and larvae at Pickering NGS A was equivalent to the reproductive output of 43,000 spawning females at last spawn and 130,000 at Pickering NGS B (Table 5). Assuming all entrained eggs and

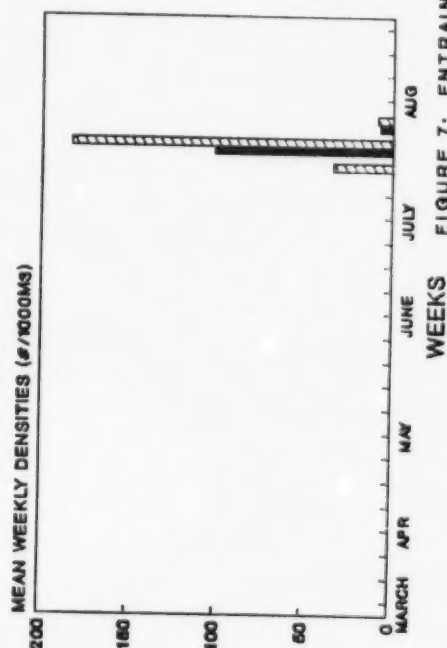
ALEWIFE EGG DENSITIES PICKERING NGS A AND B, 1988



CARP EGG DENSITIES PICKERING NGS A AND B



ALEWIFE LARVAL FISH DENSITIES PICKERING NGS A AND B



CARP LARVAL FISH DENSITIES PICKERING NGS A AND B

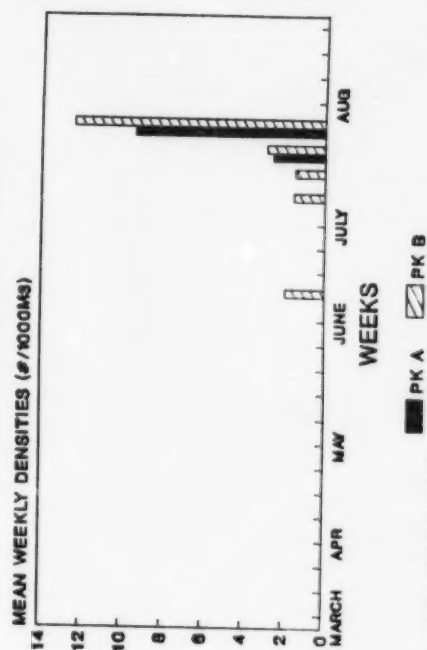


FIGURE 7: ENTRAINMENT OF FISH EGGS AND LARVAE AT PICKERING NGS, 1988.

larvae are killed, the total loss incurred through entrainment at Pickering NGS was equivalent to the reproductive output of 173,000 spawning females at last spawn.

In a simulation model developed to assess the potential effect of forage fish impingement and entrainment at Pickering NGS and Darlington NGS, increasing mortality results in the damping of population oscillation, which in the model is driven by episodes of winter kill mortality (Greig and Heltcher 1989).

As in the case of rainbow smelt, cropping by Pickering NGS may result in a reduction in size of a segment of the alewife population. Once again, the significance of this loss must be assessed in terms of its effect on recruitment to the adult population.

Walleye

Mean weekly densities of walleye eggs entrained at Pickering NGS A and B are presented in Figure 6.

Walleye eggs were caught between March 29 and April 18 with highest density of 32 eggs/1,000 m³ observed on March 29 at Pickering NGS A.

Total annual entrainment of walleye eggs at Pickering NGS A was estimated at 250,000 eggs (Table 5). This number is low compared to their fecundity which has been reported to be as high as 612,000 (Scott and Crossman 1973). Total annual entrainment of walleye eggs was not estimated for Pickering NGS B because of the limited data available from that site.

In southwestern Ontario, walleye spawning normally occurs in April at 6.7 - 8.9°C, but can occur at 5.6 - 11.1°C (Scott and Crossman 1973). Mean daily temperatures of surface waters at a location along the 12 m depth offshore from the Pickering NGS B discharge in 1988 were below both ranges in April (Ontario Hydro Research Division Report No 89-149-K) and did not exceed 5.6°C until the first week of May. However, mean daily intake temperatures monitored at the Pickering NGS B intake were within the 5.6 - 11.1°C range on all but two days from January through April (Figure 5). Recirculation of discharged water results in elevated temperatures in the intake on most days. Effluent temperatures were above this range year-round. Thus, walleye may have spawned in the intake and/or thermal plume. If spawning occurred in the intake all eggs and larvae would likely be entrained. Spawning in the discharge would result in entrainment as well as hatch advancement, both of which may reduce the chances for recruitment.

On the four occasions between March 29 and April 8, when walleye eggs were entrained, the current generally came from the east. On these occasions the eggs may have originated from the Pickering NGS B discharge. On the subsequent two dates, April 15 and 18, the current came from the west (Ontario Hydro Geotechnical and Hydraulic Engineering Department data).

Griffiths (Ontario Hydro Research Division 81-77-K) showed that early spawned walleye (i.e. before April 25) in Lake Ontario would experience, 1, 2, 3 and 4 weeks hatch advancement from exposure to 1°, 2.8°, 5°, and 8.7°C above ambient lake temperature. The early occurrence (March 29 on) of walleye eggs in our entrainment samples suggests that early spawning of walleye occurred in the vicinity of Pickering NGS. Given the possibility that walleye spawn in the thermal plume, the hypothesis that the Pickering NGS thermal discharge and physical presence may decrease walleye stocks through entrainment and hatch advancement (Greig et al. 1986) cannot be negated.

Carp

Mean weekly densities of carp eggs and larvae entrained at Pickering NGS A and B are presented in Figure 7.

Carp eggs were collected at Pickering NGS A between May 24 and July 26. Maximum egg density of 2,000 eggs/ 1,000 m³ occurred at Pickering NGS A on May 26. Carp larvae were entrained on June 8 and July 27. Highest density of larvae at Pickering NGS A was 48/1,000 m³ on July 27. At Pickering NGS B peak larval density of 39/1,000 m³ occurred on July 26.

Total annual entrainment of carp eggs was 77 million while total annual entrainment of carp larvae was 2.1 million (Table 5).

The seasonal occurrence of carp eggs and larvae in the entrainment samples is consistent with their spring to early summer spawning period (Scott and Crossman 1973).

Other Species

Sucker eggs were taken at Pickering NGS A on four occasions between March 30 and April 27. The highest density was 34 eggs/1,000 m³ on April 25. The two common sucker species in the study area are white sucker and longnose sucker. White sucker spawn in early-May to early June while longnose sucker spawn from mid-April to mid-May (Scott and Crossman 1973). However, with the elevated temperatures in the discharge and intake, spawning may occur earlier in the area of the station resulting in the early seasonal presence of eggs in the samples.

White bass or gizzard shad eggs were caught at the Pickering NGS A site between June 1 and July 7 and at Pickering NGS B between June 3 and 8. White bass and gizzard shad eggs are very similar and it could not be determined which species these eggs belonged to. White bass spawn in May or June, and gizzard shad spawn in May, June or July (Scott and Crossman 1973). Thus the timing of these eggs in the entrainment samples suggests that they could be either species.

White perch eggs were present in the June 13th, Pickering NGS A sample and the June 10th, Pickering NGS B sample. In the Bay of Quinte, Lake Ontario, this species spawns from mid-May to the end of June (Scott and Crossman 1973). The

timing of white perch eggs in the entrainment samples, then, does not suggest advanced spawning.

The only other eggs found were a cyprinid egg (unidentified) at Pickering NGS A on July 30 and a salmonid egg (unidentified) taken in the 0.5 m diameter net on March 29 at Pickering NGS B.

Live-Dead Determinations

The proportion of dead larval alewife sampled in the intake reflects the natural mortality of the population from which the larvae are drawn plus the handling mortality. Since handling mortality was not quantified, it was not possible to separate it from natural mortality. The natural mortality is a population characteristic and does not affect the estimate of spawning females represented by the entrained eggs and larvae presented in the preceding section unless it can be shown that the intake selectively entrains dead larvae.

The results of the live-dead sorting are presented in Table 7. The percentage of dead larvae in individual samples ranged from 89 to 100 at Pickering NGS A and from 87 to 100 at Pickering NGS B.

4.0 SUMMARY

- 4.1 Alewife, rainbow smelt, round whitefish and carp larvae were entrained at both stations. Eggs of these species, and of walleye, white perch, white bass or gizzard shad, sucker, and cyprinid were also entrained at one or both stations.
- 4.2 Round whitefish larvae were collected from March 15 to April 27. Annual entrainment of round whitefish larvae was equivalent to the reproductive output of 96 spawning females at last spawn: 79 at Pickering NGS A, and 17 at Pickering NGS B. The early occurrence of round whitefish larvae in entrainment samples, as well as their size structure, suggest that round whitefish spawn in the thermal plume. Therefore, the hypothesis that the thermal plume and water intake of Pickering NGS would decrease the population through egg hatch advancement and entrainment of larvae (Greig et al. 1986) may be true. However, the compensatory mechanisms that this population is capable of are not known and should be investigated.
- 4.3 Rainbow smelt eggs were entrained between March 18 and July 7. Larvae were entrained between April 29 and July 20. Annual entrainment of eggs and larvae was equivalent to the reproductive output of 46,000 spawning females at last spawn at Pickering NGS A and 65,000 at Pickering NGS B for a total of 111,000. As hypothesized, the continuous cropping of smelt by Pickering NGS could result in the reduction of a segment of the rainbow smelt population. However, the significance of this loss must be assessed in terms of recruitment to the adult population.

Table 7

NUMBERS OF LIVE AND DEAD ALEWIFE LARVAE
IN 1988 PICKERING NGS A AND B INTAKE SAMPLES

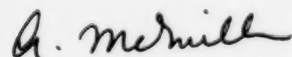
	LIVE	DEAD	% DEAD
PICKERING NGS A			
JULY 28	5	41	89
JULY 29	0	20	100
JULY 30	0	4	100
AUGUST 2	0	2	100
PICKERING NGS B			
JULY 28	4	26	87
JULY 29	4	30	88
JULY 30	0	2	100
AUGUST 2	0	2	100

- 4.4 Alewife eggs were entrained between June 20 and August 25, and larvae were entrained from July 25 to August 2. The annual entrainment of alewife eggs and larvae was equivalent to the reproductive output of 43,000 spawning females at last spawn at Pickering NGS A and 130,000 at Pickering NGS B for a total of 173,000. As hypothesized, continuous cropping of alewife by Pickering NGS A may result in the reduction of a segment of this population. However, the significance of this loss must be assessed in terms of recruitment to the adult population.
- 4.5 Walleye eggs were entrained between March 29 and April 18 at Pickering NGS A and on March 29 at Pickering NGS B. Annual entrainment of walleye eggs, at 250,000, was low compared to their fecundity which has been reported to be as high as 612,000 (Scott and Crossman 1973). However, their seasonal occurrence in the samples suggests that they spawn in the thermal plume. Given this possibility, the hypothesis that the Pickering NGS thermal discharge and cooling water usage may decrease walleye stock through entrainment and hatch advancement (Greig et al. 1986) cannot be negated.
- 4.6 Mortality of alewife larvae in the intake, which represented both natural and handling mortality, ranged from 89 to 100% at Pickering NGS A and 87 to 100% at Pickering NGS B.

ACKNOWLEDGEMENTS

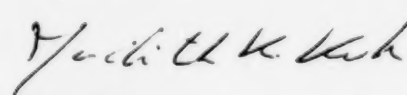
The authors are deeply indebted to Larry King who was the crew chief in charge of the Pickering field program. His adaptations of the sampling equipment and input on sampling locations and schedule, undoubtedly contributed to the success of the project. We would also like to acknowledge Tessah Olivares of the Operations Research Department who calculated the annual entrainment of the fish eggs and larvae. Steve Griffiths' help in analysing the round whitefish and walleye data and running the round whitefish egg development model is greatly appreciated.

Reviewed by:



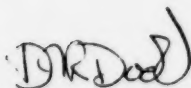
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APPENDIX 1

ENTRAINMENT SAMPLING PLATFORMS AND APPARATUS

[Abridged from OHRD Report No C89-89-K, L.P. King]

Proper placement of the pump and net sampling gear was essential in order to effectively sample water flow committed to Pickering NGS. The requirements of this study were that the water flow into the operating units of Pickering NGS "A" and Pickering NGS "B" be sampled independently, yet simultaneously; that both locations be easily accessible for operation and service, and that a regular sampling schedule be maintained during a variety of wind and wave conditions. These criteria precluded the use of the intake forebay or a mobile work platform and favoured the placement of floating work platforms. The first platform was positioned south of the Pickering NGS "A" skimmer wall while the second platform was deployed in the eastern branch of the intake channel in the water destined for Pickering NGS "B" (Figure 1).

DESCRIPTION OF EQUIPMENT

Each platform consisted of forty-eight 50 cm x 50 cm x 40 cm high, interconnecting high density polyethylene floating units (Jetfloat Ltd). When interconnected the units formed a 3.5 m x 3.5 m work area. A railing, of 1.9 cm galvanized sheet pipe was added around the platform for personnel safety. One unit was left out of the raft on the downstream corner to facilitate deployment and retrieval of sampling apparatus (0.5 m conical nets) from within the safety railing. The addition of a hinged A-frame with a top-mounted pulley (Figure 2) further increased the efficiency with which sampling gear could be deployed and retrieved.

At the Pickering "A" sampling location (Figure 1), two 450 kg concrete blocks, utilized at the former fish diversion test structure (OHRD Report 84-44-K, C82-19-K) were transferred to a position approximately 20 m upstream of the final raft position and were used to anchor the raft. Two 2.5 cm polypropylene rope lines attached the raft to the concrete blocks. A shock line of 1.6 cm polypropylene rope fastened the raft to an eye-bolt in the skimmer wall. A 27 kg anchor suspended midway along the shock line, dampened the raft's movement and maintained its position during periods of moderate wave action. Wave heights of 1 m+ were experienced at this location with no damage to sampling gear or equipment.

At the Pickering "B" sampling location, anchor lines were attached to the two most northerly RTD (Resistance Temperature Device) support structures (36 cm I-Beam) (Figure 1), positioning the raft approx. 10 m downstream of the pilings. A shock line, attached to two 27 kg steel anchors placed 20 m east of the raft, was again used to maintain the raft downstream position. Both rafts were positioned with a corner directed into the current flow to reduce drag and minimize the effects of wind generated wave action.

A 10 cm Homelite trash pump (impeller type) was positioned on each raft and used for sampling from March 29 onward. In both cases, pumps were secured to a 1.2 m x 2.4 m sheet of 19 mm plywood with eye bolts and turnbuckles. The plywood was in turn attached with ropes to strong points on the rafts perimeter. This provided a secure mounting system for the pumps. Tightening of turnbuckles was required periodically.

The sampling platform as constructed provided a stable and satisfactory means of deploying entrainment sampling gear in a protected environment.

BOTTOM SAMPLER

Bottom samplers were designed and constructed to sample round whitefish larvae which are closely associated with the bottom after hatching. The bottom sampler (Figure 4a) consisted of a 61 cm square sheet plate, attached to a sleeve of 12.7 cm steel pipe. A sampling tube (61 cm long) of 10 cm steel pipe passed through the sleeve and was adjustable from 10 to 30 cm above the steel plate. Coarse screening (2.5 x 5.0 cm steel mesh) was attached over the lower end of the sampling tube to exclude large fish, while the upper end of the tube was threaded to facilitate attachment of the flexible intake hose. The sleeve and tube assembly was inclined 25°, with the open end directed upstream. Two 27 kg anchors served to maintain its position in the intake current (Pickering "A", 15-20 cm/sec; Pickering "B" 50-60 cm/sec) and aid in achieving proper orientation.

The bottom sampler designed for the Homelite pump was approximately 5 times more effective at collecting round whitefish larvae at the Pickering NGS "A" location, than the 1 m net used at the same location over a similar time period. Between March 29 and April 29, 1988, the bottom sampler in combination with the 10 cm Homelite trash pump collected 6 round whitefish (1 larva/1800 m³) larvae while pumping 10,792 cubic meters of water, compared to 5 round whitefish larvae filtered from 47,282 cubic meters of water (1 larva/9456 m³) by the 1.0 m conical net (3:1 length to diameter ratio). At the Pickering "B" location however, two round whitefish larvae were collected by the 1.0 m net and none by the bottom sampler over the same time period (March 29 - April 13). Corresponding volumes of water sampled by the 1.0 m net and the pump at Pickering "B" were 23,245 cubic meters and 5,184 cubic meters respectively. Net collection efficiency was somewhat lower (1 larva/11,622 m³) but similar to that obtained at Pickering "A". The difference in bottom sampler catch is considerable between the two locations and may have been a function of the difference in current speed at the two sampling locations. At Pickering "A", current speed measurements obtained in front of the skimmer wall on March 15 at 2.25 m depth, ranged from 17-22 cm/sec and calculations of current velocity from 1.0 m net sets 0.5 m off bottom averaged 15 cm/sec. At the Pickering "B" location, 1.0 m net sets, 0.5 m off bottom, indicated current speeds ranged from 45-65 cm/sec. This corresponds well with cross-sectional intake velocity profiles prepared by Geotechnical and Hydraulic Engineering for a line approximately 50 m upstream of the RTD support structures (G&HE, Tech, Memorandum, 314D-G-06). The greater velocity of water passing the intake port of the bottom sampler at the Pickering "B" location (~60

cm/sec), would reduce the effective collection zone of the sampler to a greater extent than at Pickering "A" resulting in a greater chance of larvae entering the sampling tube at a horizontal velocity of 15 cm/sec (Pickering "A") than at 60 cm/sec (Pickering "A") (OHRD Memorandum A. Chan, T. Olivares, July, 1989).

MIDWATER SAMPLER

Midwater sampling for rainbow smelt and alewife larvae was conducted an integrated sampler of 10 cm PVC (polyvinyl chloride) pipe with a series of 2.5 cm holes in two rows spaced 7.6 cm apart (Figure 4b). The length of the sampling tube at Pickering "A" was 2.4 m (water depth 3.9 m) and at Pickering "B" was 1.2 m (water depth 2.4 m). In both cases, the holes were equally spaced in the two rows along the length of the tube, providing the equivalent sampling area of 10 cm piping. Samplers were anchored vertically in the water column below the leading edge of the raft with the sampling ports directed upstream.

Both bottom and midwater samplers were subject to fouling from clumps of algae (mainly Cladophora) during storm events. Samplers were removed, cleaned, and reset on approximately a biweekly basis during spring (March-May) sampling and approximately monthly during summer (June-August) sampling.

Collection of sampled material was accomplished with a 0.5 m Henson egg net (363 μ m mesh) suspended within a steel framework (Figure 2) (OHRD 86-190-K) which was submerged below the water surface. Attachment of the net to the pump discharge hose was provided by cam-lock type fittings ("Andrews"). These fittings provided swift and positive removal and reattachment of the collection net during sampling replicates.

In addition to supporting the pump, and its associated sampling equipment the raft also provided an excellent work area from which to deploy other sampling equipment (i.e. 0.5 m and 1.0 m larval tow nets). Transit between rafts and shore in the protected intake could be accomplished safely with a small ($\approx$ 5 m) boat and motor. Mooring the boat in the intake between sampling periods, precluded the need to travel the open lake waters during periods of high wind and wave activity and assured that the sampling schedule could be maintained.

The midwater sampler appeared to function effectively, although no quantitative sampling was conducted with alternative gear types during the same period for comparison. A bottom 0.5 m larval tow net, (3:1 length to diameter ratio) deployed from the Pickering "A" sampling raft between May 3 and July 25 collected smelt eggs and larvae, alewife eggs and larvae, carp eggs and larvae, and white bass or gizzard shad eggs. The same species, as well as white perch eggs, was collected by the midwater sampler at Pickering "A" during the same time period. Thus, species collected by the midwater sampler are similar to those collected by larval tow nets. Further efforts are required to compare the sampler's quantitative capabilities with those of the larval tow nets.

APPENDIX 2
PICKERING ENTRAINMENT DATA, 1988
1.0 M. CONICAL NETS

DATE	DEPTH (METERS)	LOCATION	SET #	TIME IN	TIME OUT	VOLUME FILTERED (M ³)	NO. OF SAMPLE JARS FROM SET	CONTENTS
MARCH 15	1	PKB INTAKE	1	MAR 14 - 13:30	~10:00	?	3	1 JUVENILE SMELT SAMPLE EMPTY
"	1	PKB INTAKE	2	10:21	14:27	8082.8	2	1 RWF LARVA SAMPLE EMPTY
MARCH 16	1	PKB INTAKE	1	MAR 15 - 14:41	09:51	29982.5	7	"
"	1	PKB INTAKE	2	09:58	14:10	8347.3	1	"
MARCH 17	1	PKB INTAKE	1	MAR 16 - 14:13	09:50	33059.4	4	"
MARCH 18	1	PKB INTAKE	1	MAR 17 - 09:52	13:50	29702.3	5	"
MARCH 21	1	PKB INTAKE	1	12:30	13:49	2650.7	1	71 SMELT EGGS SAMPLE EMPTY
MARCH 22	1	PKB INTAKE	1	NOT RECORDED	13:35		5	"
MARCH 23	BOT.	PKB INTAKE	1	MAR 22 - 13:45	10:30	19439.7	7	"
MARCH 24	BOT.	PKB INTAKE	1	MAR 23 - 10:32	10:55	25793.7	6	SAMPLE EMPTY 1 RWF LARVA SAMPLE EMPTY
"	BOT.	PKB INTAKE	2	10:55	14:35	6976.0	1	"
MARCH 29	BOT.	PKB INTAKE	1	MAR 28 - 13:40	09:40	14550.7	7	"
"	BOT.	PKB INTAKE	2	09:45	13:34	1366.4	4	1 RWF LARVA SAMPLE EMPTY
"	BOT.	PKA INTAKE	1	13:53	15:15	349.9	1	"
MARCH 30	BOT.	PKA INTAKE	1	10:23	12:55	425.9	12	SAMPLE EMPTY 1 RWF LARVA, 1 WALLEYE EGG 1 RWF LARVA SAMPLE EMPTY 1 SUCKER EGG 1 RWF LARVA SAMPLE EMPTY 2 SMALL EGGS, NOT SAVED SAMPLE EMPTY

"	BOT.	PKA INTAKE	1	13:53	15:15	349.9	1	9 WALLEYE EGGS
MARCH 30	BOT.	PKA INTAKE	1	10:23	12:55	425.9	12	"
								"
								1 RWF LARVA, 1 WALLEYE EGG
								SAMPLE EMPTY
								1 RWF LARVA
								SAMPLE EMPTY
								1 SUCKER EGG
								1 RWF LARVA
								SAMPLE EMPTY
								2 SMALL EGGS, NOT SAVED
								SAMPLE EMPTY
MARCH 31	BOT.	PKB INTAKE	1	09:31	11:08	3047.6	2	"
" *	BOT.	PKA INTAKE	1	11:00	15:15	1.8	1	2 SMELT EGGS
APRIL 3	BOT.	PKA INTAKE	1	10:23	15:24	3790.2	1	SAMPLE EMPTY
"	BOT.	PKB INTAKE	1	10:03	11:57	2781.3	1	"
APRIL 5	BOT.	PKA INTAKE	1	10:07	15:20	1645.9	1	SAMPLE EMPTY
"	BOT.	PKB INTAKE	1	09:52	11:50	3146.9	1	"
APRIL 7	BOT.	PKA INTAKE	1	09:31	15:05	974.7	2	23 SMT EGGS, 1 RWF LARVA,
								1 WB OR GZS
								SAMPLE EMPTY
" *	BOT.	PKB INTAKE	1	09:11	11:06	2581.2	1	"
APRIL 8	BOT.	PKA INTAKE	1	09:29	15:08	3656.3	1	"
"	BOT.	PKB INTAKE	1	09:12	11:06		1	81 SMELT EGGS
APRIL 11	BOT.	PKA INTAKE	1	10:22	15:55	493.6	1	SAMPLE EMPTY
"	BOT.	PKB INTAKE	1	10:03	12:08		1	2 RWF LARVAE
APRIL 13 **	BOT.	PKA INTAKE	2	APR 11 - 15:59	9:10	21004.3	1	SAMPLE EMPTY
"	BOT.	PKA INTAKE	1	09:18	15:46	1714.6	1	SAMPLE EMPTY
"	BOT.	PKB INTAKE	1	09:24	12:18	2233.0	1	SAMPLE EMPTY
APRIL 14	BOT.	PKA INTAKE	1	APR 13 - 15:49	10:18	6365.7	1	1 SMELT EGG
APRIL 15	BOT.	PKA INTAKE	1	09:25	15:08	1948.3	1	SAMPLE EMPTY
"	BOT.	PKB INTAKE	1	09:05	11:06	3096.2	1	SAMPLE EMPTY
APRIL 18 **	BOT.	PKA INTAKE	1	09:45	15:34	59.9	4	SAMPLE EMPTY
								SAMPLE LOST
								SAMPLE EMPTY
"	BOT.	PKB INTAKE	1	09:18	11:33	2571.1	3	1 RWF LARVA
								SAMPLE EMPTY
								SAMPLE EMPTY
APRIL 20	BOT.	PKA INTAKE	1	10:12	15:50	3715.0	1	65 SMELT EGGS
"	BOT.	PKB INTAKE	1	09:48	11:48	3414.9	1	1 WHITE SUCKER LARVA
APRIL 22 **	BOT.	PKA INTAKE	1	09:16	15:05	10329.2	1	SAMPLE EMPTY
"	BOT.	PKB INTAKE	1	09:00	10:53	8806.9	1	"
APRIL 25	BOT.	PKA INTAKE	1	09:45	15:37	2558.8	1	3 SMELT EGGS
"	BOT.	PKB INTAKE	1	09:25	11:20	2875.6	1	SAMPLE EMPTY
APRIL 27	BOT.	PKA INTAKE	1	09:17	15:15	2716.7	5	"
								"
								"
								"
"	BOT.	PKB INTAKE	1	08:54	10:50	2504.3	1	1 EGG MEMBRANE (WALLEYE?)
APRIL 29	BOT.	PKA INTAKE	1	09:29	15:10	2917.1	1	SAMPLE EMPTY
"	BOT.	PKB INTAKE	1	09:04	10:55	2649.6	1	1 EGG MEMBRANE (SUCKER ?)

* METER SHAFT BENT, INACCURATE
 ** QUESTIONABLE METER READINGS

APPENDIX 3

PICKERING ENTRAINMENT DATA, 1988
 0.5 M. BOTTOM CONICAL NETS
 PICKERING A SAMPLING RAFT

DATE	LOCATION	TIME IN	TIME OUT	DURATION OF SET	CONTENTS
MAY 3	PKA INTAKE	10:52	12:56	02:04	SAMPLE EMPTY
MAY 5	"	11:21	12:51	01:30	32 SMT EGGS, 1 WB OR GZS EGG
MAY 9	"	09:30	11:08	01:38	81 SMT EGGS
MAY 12	"	09:30	10:45	01:15	12 SMT EGGS
MAY 16	"	13:15	14:30	01:15	3 SMT EGGS, 1 SMT LARVA
MAY 18	"	09:15	10:30	01:15	1 SMT EGG
MAY 20	"	09:13	10:26	01:13	3 SMT EGGS, 2 SMT LARVA
MAY 24	"	09:40	10:55	01:15	2 SMT EGGS
MAY 26	"	08:55	10:10	01:15	SAMPLE EMPTY
MAY 27	"	08:55	10:10	01:15	11 CARP EGGS, 1 ALE EGG
MAY 30	"	09:20	10:35	01:15	SAMPLE EMPTY
JUNE 1	"	09:10	10:25	01:15	"
JUNE 3	"	09:30	10:45	01:15	"
JUNE 6	"	09:40	10:55	01:15	1 CARP EGG
JUNE 8	"	08:10	09:25	01:15	2 CARP EGGS
JUNE 10	"	08:20	09:35	01:15	4 SMT EGGS, 1 ALE EGG
JUNE 13	"	09:50	11:05	01:15	1 EGG (UNKNOWN)
JUNE 15	"	09:00	10:15	01:15	SAMPLE EMPTY
JUNE 17	"	09:05	10:20	01:15	"
JUNE 20	"	09:15	10:30	01:15	4 SMT EGGS, 3 CARP EGGS
JUNE 23	"	08:40	09:55	01:15	5 SMT EGGS
JUNE 27	"	09:42	10:39	00:57	SAMPLE EMPTY
JUNE 30	"	08:20	09:35	01:15	"
JULY 4	"	09:00	10:15	01:15	"
JULY 7	"	08:50	10:05	01:15	"
JULY 11	"	10:15	11:30	01:15	"
JULY 13	"	14:56	15:46	00:50	14 ALE EGGS
JULY 15	"	09:15	10:05	00:50	2 ALE EGGS, 1 CARP EGG
JULY 18	"	10:20	11:10	00:50	1 EGG MEMBRANE (ALE ?)
JULY 20	"	10:00	10:50	00:50	1 EGG MEMBRANE (ALE ?)
JULY 22	"	10:30	11:20	00:50	47 ALE EGGS
JULY 25	"	10:03	11:01	00:58	69 ALE EGGS, 1 CARP EGG
					1 ALE LARVA, 3 CARP LARVA

APPENDIX 3 (CONT.)

PICKERING ENTRAINMENT DATA, 1988
0.5 M. SURFACE LARVAL TOW NETS

DATE	LOCATION	SET #	TIME IN	TIME OUT	DURATION OF SET	CONTENTS
APRIL 20	PKA INTAKE	1	12:14	13:58	1:44	SAMPLE EMPTY
"	PKB INTAKE	1	12:02	13:45	1:43	"
APRIL 22	PKA INTAKE	1	11:05	12:54	1:49	"
"	PKB INTAKE	1	09:07	12:45	3:38	"
APRIL 25	PKA INTAKE	1	11:45	13:30	1:45	"
"	PKB INTAKE	1	11:32	13:19	1:47	"
APRIL 27	PKA INTAKE	1	11:09	13:10	2:01	32 SMELT EGGS 1 WB OR GZS EGG 6 ALEWIFE EGGS
"	PKB INTAKE	1	10:56	12:57	2:01	SAMPLE EMPTY
APRIL 29	PKA INTAKE	1	09:33	11:16	1:43	"
"	PKA INTAKE	2	11:17	13:08	1:51	"
"	PKB INTAKE	1	09:13	11:00	1:47	"
"	PKB INTAKE	2	11:05	12:58	1:53	"
JULY 27	PKA INTAKE	1	09:33	10:13	0:40	73 ALEWIFE EGGS 7 CARP LARVAE
"	PKB INTAKE	1	09:01	09:56	0:55	1 ALEWIFE EGG 40 ALEWIFE LARVAE 2 CARP LARVAE

APPENDIX 4

PICKERING ENTRAINMENT DATA, 1988
PASSIVE SAMPLERS, COMMON INTAKE

DATE	LOCATION	SET #	SAMPLE JARS		TIME IN	TIME OUT	CONTENTS
			FROM SET				
APRIL 13	EAST #1	1	0		11:00(APRIL 11)	09:50	SAMPLE EMPTY
"	EAST #2	1	0		11:12(APRIL 11)	09:57	SAMPLE EMPTY
"	EAST #3	1	0		11:21(APRIL 11)	10:03	SAMPLE EMPTY
"	WEST	1	0		11:29(APRIL 11)	10:08	SAMPLE EMPTY
APRIL 14	EAST #1	1	1		09:55(APRIL 13)	10:32	SAMPLE EMPTY
"	EAST #2	1	1		10:02(APRIL 13)	10:37	SAMPLE EMPTY
"	EAST #3	1	1		10:07(APRIL 13)	10:43	1 EGG MEMBRANE (SUCKER ?)
"	WEST	1	1		10:14(APRIL 13)	10:50	SAMPLE EMPTY
APRIL 15	EAST #1	1	1		10:36(APRIL 14)	13:50	1 SUCKER EGG
"	EAST #2	1	2		10:42(APRIL 14)	13:53	5 SUCKER EGGS
"							5 SUCKER EGGS
"	EAST #3	1	1		10:48(APRIL 14)	13:48	SAMPLE EMPTY
"	WEST	1	1		10:56(APRIL 14)	13:45	1 RWF LARVA
APRIL 19	EAST #1	1	2		10:12(APRIL 18)	09:45	SAMPLE EMPTY
"							SAMPLE EMPTY
"	EAST #2	1	2		10:08(APRIL 18)	09:50	SAMPLE EMPTY
"							SAMPLE EMPTY
"	EAST #3	1	2		10:04(APRIL 18)	09:39	SAMPLE EMPTY
"							1 SUCKER EGG
"	WEST	1	2		09:58(APRIL 18)	09:34	SAMPLE EMPTY
"							SAMPLE EMPTY
APRIL 20	EAST #1	1	1		09:49(APRIL 19)	10:43	4 SUCKER EGGS
"	EAST #2	1	1		09:46(APRIL 19)	10:37	2 SUCKER EGGS
"	EAST #3	1	1		09:43(APRIL 19)	10:33	1 WB OR G2S EGG
"	WEST	1	1		09:38(APRIL 19)	10:28	SAMPLE EMPTY
APRIL 21	EAST #1	1	1		10:46(APRIL 20)	09:25	SAMPLE EMPTY
"	EAST #2	1	1		10:42(APRIL 20)	09:30	SAMPLE EMPTY
"	EAST #3	1	1		10:36(APRIL 20)	09:33	SAMPLE EMPTY
"	WEST	1	2		10:32(APRIL 20)	09:37	SAMPLE EMPTY
"							SAMPLE EMPTY
APRIL 22	EAST #1	1	1		09:28(APRIL 21)	09:47	SAMPLE EMPTY
"	EAST #2	1	1		09:32(APRIL 21)	09:42	SAMPLE EMPTY
"	EAST #3	1	1		09:36(APRIL 21)	09:38	SAMPLE EMPTY
"	WEST	1	1		09:42(APRIL 21)	09:34	3 SUCKER EGGS, 1 ALE. EGG
"							1 W. BASS OR G. SHAD EGG
APRIL 26	EAST #1	1	1		10:30(APRIL 25)	10:10	SAMPLE EMPTY
"	EAST #2	1	1		10:22(APRIL 25)	10:02	SAMPLE EMPTY
"	EAST #3	1	1		10:13(APRIL 25)	09:58	SAMPLE EMPTY
"	WEST	1	1		10:04(APRIL 25)	09:50	SAMPLE EMPTY
APRIL 27	EAST #1	1	1		10:10(APRIL 26)	09:32	SAMPLE EMPTY
"	EAST #2	1	1		10:06(APRIL 26)	09:37	SAMPLE EMPTY
"	EAST #3	1	1		10:01(APRIL 26)	09:43	SAMPLE EMPTY

"	WEST	1	1	09:57(APRIL 26)	09:48	SAMPLE EMPTY
APRIL 28	EAST #1	1	7	09:36(APRIL 27)	10:14	SAMPLE EMPTY
"						SAMPLE EMPTY
"						13 SMELT EGGS, 8 ALEWIFE EGGS
"						264 SMELT EGGS
"						SAMPLE EMPTY
"						SAMPLE EMPTY
"						SAMPLE EMPTY
"	EAST #2	1	5	09:42(APRIL 27)	10:10	SAMPLE EMPTY
"						SAMPLE EMPTY
"						575 SMELT EGGS
"						SAMPLE EMPTY
"						SAMPLE EMPTY
"	EAST #3	1	1	09:47(APRIL 27)	10:06	7 SMELT EGGS, 1 SUCKER EGG
"	WEST	1	1	09:51(APRIL 27)	10:00	3 SMELT EGGS, 2 SUCKER EGGS
APRIL 29	EAST #1	1		10:18(APRIL 28)	09:45	1 SALMONID EGG
"	EAST #2	1		10:13(APRIL 28)	09:48	1 SUCKER EGG
"	EAST #3	1		10:09(APRIL 28)	09:54	SAMPLE EMPTY
"	WEST	1		10:05(APRIL 28)	10:00	SAMPLE EMPTY

APPENDIX 5

PICKERING ENTRAINMENT DATA, 1988
 NET-AND-PUMP SYSTEM
 PICKERING A SAMPLING RAFT

DATE	SAMPLE #	TIME ON	TIME OFF	DURATION OF SET	SPECIES	# OF EGGS	# OF LARVAE	TOTAL (M ³) OF WATER PUMPED
MARCH 29	1	9:20	11:25	02:05	-	0	0	284
"	2	11:30	13:40	02:10	RWF	0	2	295
"	3	13:50	15:10	01:20	WALLEYE	10	0	182
					WALLEYE	15	0	
MARCH 31	1	10:07	11:44	01:37	-	0	0	220
"	2	11:50	13:32	01:42	-	0	0	232
"	3	13:42	15:15	01:33	WALLEYE	1	0	211
APRIL 3	1	10:27	12:16	01:49	-	0	0	247
"	2	12:22	14:02	01:40	-	0	0	227
"	3	14:07	15:23	01:44	-	0	0	236
APRIL 5	1	10:22	12:07	01:45	-	0	0	238
"	2	12:15	13:49	01:34	-	0	0	213
"	3	13:59	15:20	01:19	-	0	0	179
APRIL 7	1	9:38	11:30	01:52	-	0	0	254
"	2	11:32	13:11	01:39	RWF	0	1	225
					SMELT	39	0	
"	3	13:15	15:04	01:49	SMELT	48	0	247
					SMELT	26	0	
APRIL 8	1	9:32	11:22	01:50	SMELT	106	0	249
					WALLEYE	1	0	
"	2	11:26	13:10	01:44	-	0	0	236
"	3	13:15	15:03	01:48	-	0	0	245
APRIL 11	1	10:31	12:24	01:53	SMELT	573	0	257
"	2	12:27	14:09	01:36	-	0	0	218
"	3	14:24	15:57	01:33	-	0	0	211
APRIL 13	1	9:26	~11:26	02:00	SMELT	2487	0	272
"	2	12:12	13:50	01:38	-	0	0	222
"	3	13:54	15:43	01:49	-	0	0	247
APRIL 15	1	9:33	11:18	01:45	SMELT	1233	0	238
"	2	11:25	13:13	01:48	SMELT	1215	0	245
"	3	13:28	15:08	01:40	WALLEYE	1	0	227
APRIL 18	1	9:48	11:48	02:00	SMELT	415	0	272

					SMELT	71	0	
					SMELT	250	0	
					SMELT	134	0	
					SMELT	153	0	
					-	0	0	
"	2	11:57	13:49	01:52	WALLEYE	3	0	254
					-	0	0	
					-	0	0	
"	3	14:00	15:33	01:33	SMELT	1	0	211
					UNKNOWN	2	0	
					SMELT	830	0	
					SMELT	708	0	
					RWF		1	
					SMELT	529	0	211
APRIL 20	1	10:16	12:07	01:51	SMELT	56	0	252
"	2	12:12	13:58	01:46	-	0	0	241
"	3	14:05	15:47	01:42	-	0	0	232
APRIL 22	1	9:24	11:10	01:46	SMELT	945	0	241
"	2	11:14	12:53	01:39	SUCKER	109	0	225
					SMELT	3	0	
"	3	12:57	14:59	02:02	-	0	0	277
APRIL 25	1	9:51	11:40	01:49	SMELT	1065	0	247
"	2	11:44	13:30	01:46	SUCKER	2	0	241
"	3	13:35	15:24	01:51	-	0	0	252
APRIL 27	1	9:22	11:08	01:46	SMELT	303	0	241
					SMELT	305	0	
					SMELT	910	0	
					SMELT	592	0	
"	2	11:12	13:10	01:58	RWF	0	1	268
					SUCKER	1	0	
					SMELT	460	0	
					SMELT	495	0	
"	3	13:14	15:05	01:51	RWF	0	1	252
					SUCKER	1	0	
					SUCKER	1	0	
					SUCKER	4	0	
APRIL 29	1	9:35	11:14	01:39	-	0	0	225
"	2	11:18	13:08	01:50	SMELT	868	0	250
"	3	13:15	15:07	01:52	-	0	0	254
MAY 2	1	12:25	13:45	01:20	SMELT	38	0	182
MAY 5	1	11:24	12:48	01:24	SMELT	86	0	191
MAY 6	1	10:45	12:15	01:30	SMELT	20	0	204

MAY 9	1	9:43	11:02	01:19	SMELT	83	1	179
					SMELT	0	1	
MAY 12	1	8:25	9:40	01:15	SMELT	38	0	170
MAY 16	1	11:05	13:05	02:00	SMELT	7	0	272
MAY 18	1	9:05	10:20	01:15	SMELT	7	0	170
MAY 20	1	9:15	10:30	01:15	SMELT	13	0	170
MAY 24	1	9:45	11:00	01:15	CARP	7	0	170
MAY 26	1	8:50	10:05	01:15	CARP	615	0	170
					SMELT	16		
MAY 27	1	8:50	10:05	01:15	CARP	50	0	170
					SMELT	10		
MAY 30	1	9:20	10:35	01:15	CARP	24	0	170
					SMELT	6		
JUNE 1	1	9:05	10:22	01:17	CARP	20	0	175
					WB OR GZS	1		
					SMELT	9		
JUNE 3	1	9:35	10:50	01:15	CARP	1	0	170
JUNE 6	1	9:45	11:00	01:15	WB OR GZS	2	0	170
					CARP	48		
JUNE 8	1	8:05	9:20	01:15	CARP	10	0	170
					WB OR GZS	5		
JUNE 10	1	8:25	9:40	01:15	CARP	1	0	170
					WB OR GZS	3		
JUNE 13	1	9:45	11:00	01:15	W. PERCH	2	0	170
					UNKNOWN	4		
JUNE 15	1	8:55	10:10	01:15	-	0	0	170
JUNE 17	1	9:00	10:15	01:15	-	0	0	170
JUNE 20	1	9:20	10:35	01:15	CARP	46	0	170
					SMELT	4		
					WB OR GZS	10		
					ALEWIFE	27		
JUNE 23	1	8:35	9:50	01:15	CARP	3	0	170
					ALEWIFE	1		
JUNE 27	1	9:23	10:38	01:15	-	0	0	170
JUNE 30	1	8:25	9:40	01:15	-	0	0	170
JULY 4	1	9:05	10:20	01:15	-	0	0	170
JULY 7	1	8:45	10:00	01:15	SMELT	4	3	170
					ALEWIFE	14		
					CARP	1		
					WB OR GZS	2		

JULY 11	1	10:10	11:25	01:15	ALEWIFE	20	0	170
JULY 13	1	14:56	15:46	00:50	ALEWIFE	24	0	114
JULY 15	1	9:10	10:00	00:50	-	0	0	114
JULY 18	1	10:15	11:05	00:50	ALEWIFE	4	0	114
JULY 20	1	9:55	10:45	00:50	ALEWIFE	21	0	114
JULY 22	1	10:25	11:15	00:50	ALEWIFE	150	0	114
					CARP	2		
JULY 25	1	10:08	11:01	00:53	ALEWIFE	40	2	120
					CARP	1	1	
JULY 26	1	9:50	10:06	00:16	ALEWIFE	19	0	36
"	2	10:10	10:25	00:15	ALEWIFE	5	0	34
"	3	10:28	10:47	00:19	ALEWIFE	2	0	43
JULY 27	1	9:20	10:12	00:52	ALEWIFE	7	16	118
					CARP	0	2	
JULY 28	1	12:56	13:11	00:15	ALEWIFE	1	2	34
					ALEWIFE	0	6	
"	2	13:15	13:32	00:17	ALEWIFE	12	2	39
					ALEWIFE	0	6	
"	3	13:35	13:55	00:20	ALEWIFE	9	0	45
					ALEWIFE	0	14	
JULY 29	1	9:20	9:35	00:15	ALEWIFE	4	0	34
					ALEWIFE	0	6	
"	2	9:39	9:56	00:17	ALEWIFE	3	4	39
					ALEWIFE	0	9	
"	3	10:00	10:18	00:18	ALEWIFE	6	0	41
					ALEWIFE	0	15	
JULY 30	1	13:27	13:43	00:16	ALEWIFE	24	0	36
					ALEWIFE	0	1	
"	2	13:46	14:03	00:17	ALEWIFE	20	0	39
"	3	14:08	14:25	00:17	-	0	0	39
					CYPRINID	0	1	
AUGUST 2	1	9:21	9:40	00:19	ALEWIFE	11	0	43
"	2	9:45	10:00	00:15	ALEWIFE	4	0	34
					ALEWIFE	0	1	
"	3	10:04	10:20	00:16	ALEWIFE	5	0	36
					ALEWIFE	0	1	
AUGUST 4	1	8:45	9:35	00:50	ALEWIFE	63	0	114
AUGUST 8	1	10:25	11:15	00:50	ALEWIFE	2	0	114
AUGUST 10	1	-	-	00:50	ALEWIFE	4	0	114
AUGUST 12	1	8:15	9:05	00:50	-	0	0	114
AUGUST 15	1	9:28	10:18	00:50	-	-	-	114
AUGUST 17	1	9:43	10:34	00:51	ALEWIFE	7	0	116
AUGUST 19	1	10:20	11:10	00:50	-	0	0	114
AUGUST 22	1	10:20	11:10	00:50	-	-	-	114
AUGUST 25	1	11:30	12:20	00:50	ALEWIFE	10	0	114
AUGUST 29	1	10:30	11:20	00:50	-	0	0	114
SEPTEMBER 1	1	8:54	9:44	00:50	-	0	0	114

PK A PUMP WAS CALCULATED AT 2270 LITRES/MINUTE

APPENDIX 6

 PICKERING ENTRAINMENT DATA, 1988
 NET-AND-PUMP SYSTEM
 PICKERING B SAMPLING RAFT

DATE	SAMPLE #	TIME ON	TIME OFF	DURATION OF SET	SPECIES	# OF EGGS	# OF LARVAE	TOTAL (M ³) OF WATER PUMPED
MARCH 29	1	9:55	11:38	01:43	UNKNOWN	1	0	207
"	2	11:42	13:28	01:46	-	0	0	213
"	3	13:32	15:27	01:55	-	0	0	231
"					SALMONID	1	0	
"					WALLEYE	2	0	
MARCH 31	1	9:44	11:31	01:47	-	0	0	215
"	2	11:36	13:17	01:41	-	0	0	203
"	3	13:25	15:00	01:35	-	0	0	191
APRIL 3	1	10:11	12:03	01:52	-	0	0	225
"	2	12:07	13:51	01:44	-	0	0	209
"	3	13:57	15:34	01:37	-	0	0	195
APRIL 5	1	10:01	11:54	01:53	-	0	0	227
"	2	12:02	13:39	01:37	-	0	0	195
"	3	13:45	15:10	01:25	-	0	0	171
APRIL 7	1	9:20	11:10	01:50	-	0	0	221
"	2	11:14	13:01	01:45	-	0	0	211
"	3	13:05	14:58	01:53	SMELT	39	0	227
APRIL 8	1	9:19	11:09	01:50	-	0	0	221
"	2	11:15	13:01	01:46	SMELT	328	0	213
"	3	13:05	14:55	01:50	-	0	0	221
APRIL 11	1	12:16	13:38	01:22	SMELT	301	0	165
"	2	12:16	13:58	01:42	-	0	0	205
"	3	14:02	15:45	01:43	-	0	0	207
APRIL 13	1	9:40	~11:40	02:00	-	0	0	241
"	2	12:25	13:59	01:34	SMELT	270	0	189
"	3	14:03	15:34	01:31	-	0	0	183
APRIL 15	1	9:14	11:06	01:52	SMELT	1215	0	225
"	2	11:10	13:00	01:50	WHITEFISH	2	0	225
"	3	13:05	15:00	01:55	SMELT	71	0	221
APRIL 18	1	9:27	11:36	02:09	-	0	0	231
"	2	11:42	13:38	01:56	SMELT	620	0	259
"	3	13:43	15:48	02:05	-	0	0	233
APRIL 20	1	10:02	11:50	01:48	-	0	0	251
"	2	11:57	13:47	01:50	SMELT	1287	0	217
"	3	13:50	15:39	01:49	-	0	0	221
APRIL 22	1	9:09	10:57	01:48	-	0	0	219
"	2	11:03	12:43	01:40	SMELT	137	0	217
"	3	12:46	14:50	02:04	-	0	0	201
APRIL 25	1	9:35	11:27	01:52	-	0	0	249
"	2	11:33	13:18	01:45	SMELT	502	0	225
"	3	13:24	15:14	01:50	-	0	0	211
APRIL 27	1	9:04	10:55	01:51	-	0	0	221
"	2	11:02	12:59	01:57	SMELT	488	0	223
"	3	13:05	14:50	01:45	-	0	0	235
"					-	0	0	211
"					-	0	0	
"					NONE	0	0	
"					NONE	0	0	
"					-	0	0	
"					SMELT	2	0	
APRIL 29	1	9:17	10:59	01:42	-	0	0	205
"	2	11:06	12:58	01:52	SMELT	237	1	225
"	3	13:02	14:57	01:55	-	0	0	231
MAY 2	1	13:30	14:40	01:10	SMELT	42	0	141
MAY 5	1	11:38	13:02	01:24	SMELT	0	3	169
"					SMELT	38	0	
MAY 6	1	11:00	12:30	01:30	SMELT	21	0	181
MAY 9	1	9:59	11:21	01:22	SMELT	72	1	165
MAY 12	1	9:15	10:30	01:15	SMELT	45	0	151
MAY 16	1	11:55	13:10	01:15	SMELT	22	0	151
MAY 18	1	9:20	10:35	01:15	SMELT	4	0	151
MAY 20	1	9:39	10:49	01:10	SMELT	27	0	141
MAY 24	1	9:30	10:45	01:15	SMELT	9	0	151
"					CARP	2	0	
MAY 26	1	8:40	9:55	01:15	CARP	27	0	151
"					SMELT	8	0	
MAY 27	1	9:05	10:20	01:15	CARP	13	0	151
"					SMELT	2	0	
"					CARP	32	0	
"					SMELT	10	0	
MAY 30	1	9:15	10:30	01:15	CARP	1	0	151
"					CARP	21	0	
JUNE 1	1	8:55	10:10	01:15	CARP	12	0	151

JUNE 3	1	9:20	10:35	01:15	SMELT	5		
JUNE 6	1	9:35	10:50	01:15	WB OR GZS	2	0	151
					CARP	68	0	151
					WB OR GZS	2		
					-	0	0	
JUNE 8	1	8:15	9:30	01:15	CARP	3	1	151
					WB OR GZS	2		
JUNE 10	1	8:10	9:25	01:15	SMELT	0	4	151
					CARP	8		
					UNKNOWN	3		
					W. PERCH	1		
JUNE 13	1	9:35	10:50	01:15	UNKNOWN	10	0	151
JUNE 15	1	8:45	10:00	01:15	-	0	0	151
JUNE 17	1	8:40	9:55	01:15	SMELT	0	8	151
JUNE 20	1	9:10	10:25	01:15	CARP	41	0	151
					SMELT	2		
					ALEWIFE	3		
JUNE 23	1	8:50	10:05	01:15	SMELT	1	1	151
					ALEWIFE	10		
					CARP	31		
JUNE 27	1	9:16	10:31	01:15	CARP	3	0	151
					ALEWIFE	1		
JUNE 30	1	8:16	9:31	01:15	SMELT	0	4	151
JULY 4	1	8:50	10:05	01:15	SMELT	0	1	151
JULY 7	1	10:20	11:35	01:15	ALEWIFE	5	0	151
JULY 11	1	9:55	11:10	01:15	ALEWIFE	53	0	151
					SMELT	2	2	
					CARP	18	1	
JULY 13	1	14:46	15:36	00:50	ALEWIFE	31	0	101
JULY 15	1	9:00	9:50	00:50	ALEWIFE	13	0	101
					CARP	2		
JULY 18	1	10:05	10:55	00:50	ALEWIFE	7	0	101
					CARP	8		
JULY 20	1	9:45	10:35	00:50	ALEWIFE	50	0	101
					SMELT	0	1	
					CARP	1	0	
JULY 22	1	10:15	11:05	00:50	ALEWIFE	28	0	101
JULY 25	1	9:53	10:48	00:50	ALEWIFE	422	24	101
					CARP	4	2	
JULY 26	1	9:35	9:53	00:18	ALEWIFE	32	4	36
					CARP	1	2	
"	2	9:57	10:15	00:18	ALEWIFE	58	0	36
					CARP	1	1	
"	3	10:19	10:34	00:15	ALEWIFE	8	0	30
					CARP	0	1	
JULY 27	1	9:01	9:55	00:54	ALEWIFE	155	28	109
					CARP	0	3	
JULY 28	1	10:34	10:49	00:15	ALEWIFE	30	0	30
					ALEWIFE	0	11	
"	2	10:53	11:12	00:19	ALEWIFE	30	4	38
					ALEWIFE	0	8	
"	3	11:17	11:33	00:16	ALEWIFE	25	1	32
					ALEWIFE	0	22	
JULY 29	1	10:20	10:35	00:15	ALEWIFE	11	0	30
					ALEWIFE	0	5	
"	2	10:38	10:55	00:17	ALEWIFE	14	0	34
					ALEWIFE	0	6	
"	3	10:59	11:17	00:18	ALEWIFE	4	0	36
					ALEWIFE	0	9	
JULY 30	1	10:17	10:33	00:16	ALEWIFE	45	0	32
					ALEWIFE	0	1	
"	2	10:37	10:54	00:17	ALEWIFE	54	0	34
					ALEWIFE	0	2	
"	3	11:00	11:17	00:17	ALEWIFE	87	0	34
					ALEWIFE	0	2	
AUGUST 2	1	9:14	9:30	00:16	ALEWIFE	10	0	32
					ALEWIFE	0	1	
"	2	9:34	9:50	00:16	ALEWIFE	19	0	32
					ALEWIFE	0	1	
"	3	9:54	10:12	00:18	ALEWIFE	11	0	36
AUGUST 4	1	8:35	9:20	00:45	ALEWIFE	101	0	90
AUGUST 8	1	10:15	11:05	00:50	ALEWIFE	3	0	101
AUGUST 10	1	-	-	00:50	ALEWIFE	5	0	101
AUGUST 12	1	8:05	8:55	00:50	ALEWIFE	70	0	101
AUGUST 15	1	10:36	11:26	00:50	ALEWIFE	64	0	101
AUGUST 17	1	10:18	11:08	00:50	ALEWIFE	9	0	101
AUGUST 19	1	12:10	13:00	00:50	-	0	0	101
AUGUST 22	1	12:00	12:50	00:50	-	-	-	101
AUGUST 25	1	11:20	12:10	00:50	ALEWIFE	2	0	101

PK B PUMP WAS CALCULATED AT 2010 LITRES/MINUTE